THREE D IFY®
The Power of Scalability and Flexibility

MINERAL VALUATION BASED ON UNCERTAINTY – INTRODUCING HYBRID NET PRESENT VALUE

Presented by:

Veriyadi, MSc (CSM), Ph.D (WITS), MAusIMM

Johannesburgh, 1st October 2025

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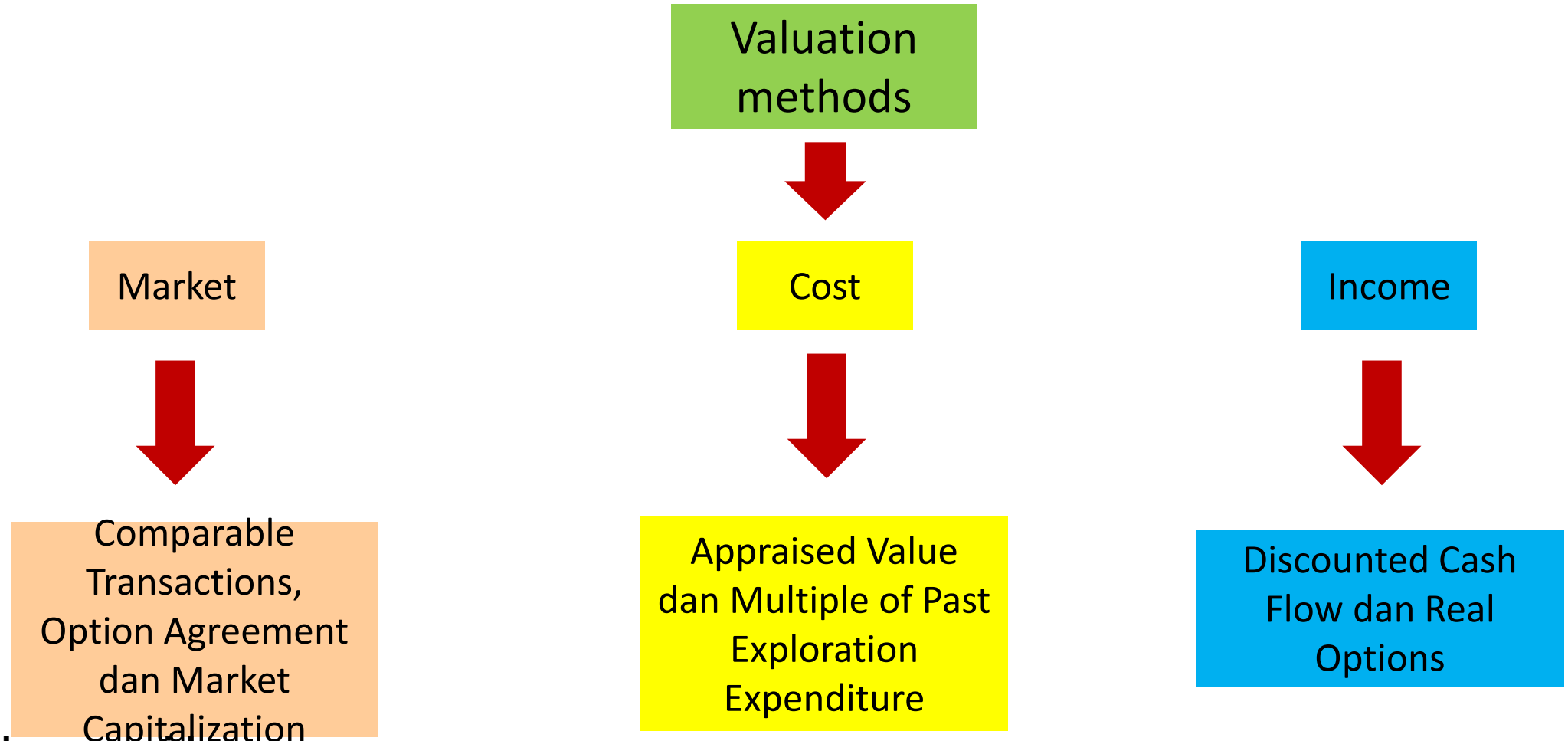
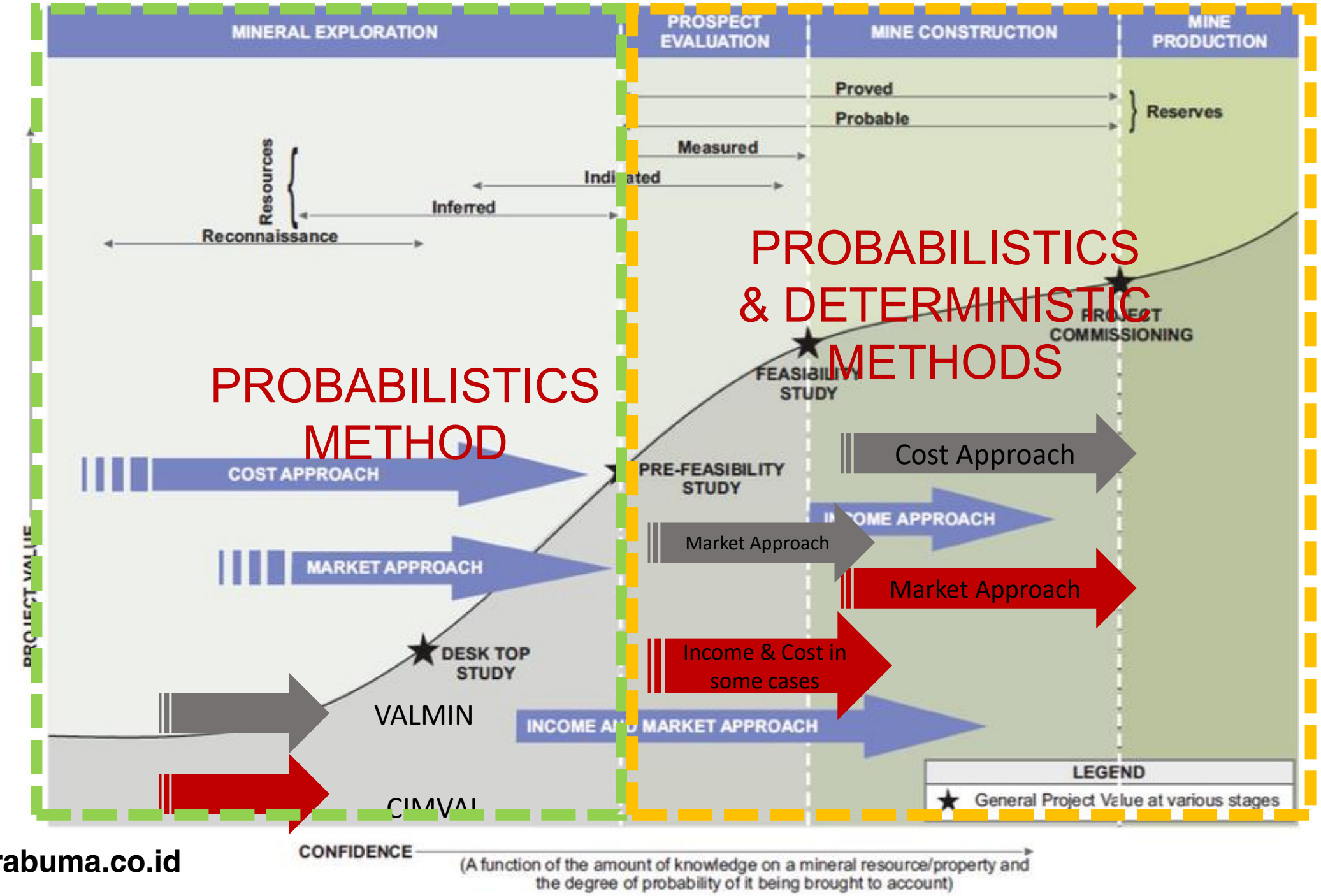
OUTLINE

1. Mine Valuation Methods
2. NPV Evolution
3. Artificial Neural Networks (ANN)
4. Metaheuristics Model – Bat Algorithm (BA)
5. Hybrid Net Present Value – ANN – BA

1. MINE VALUATION METHODS





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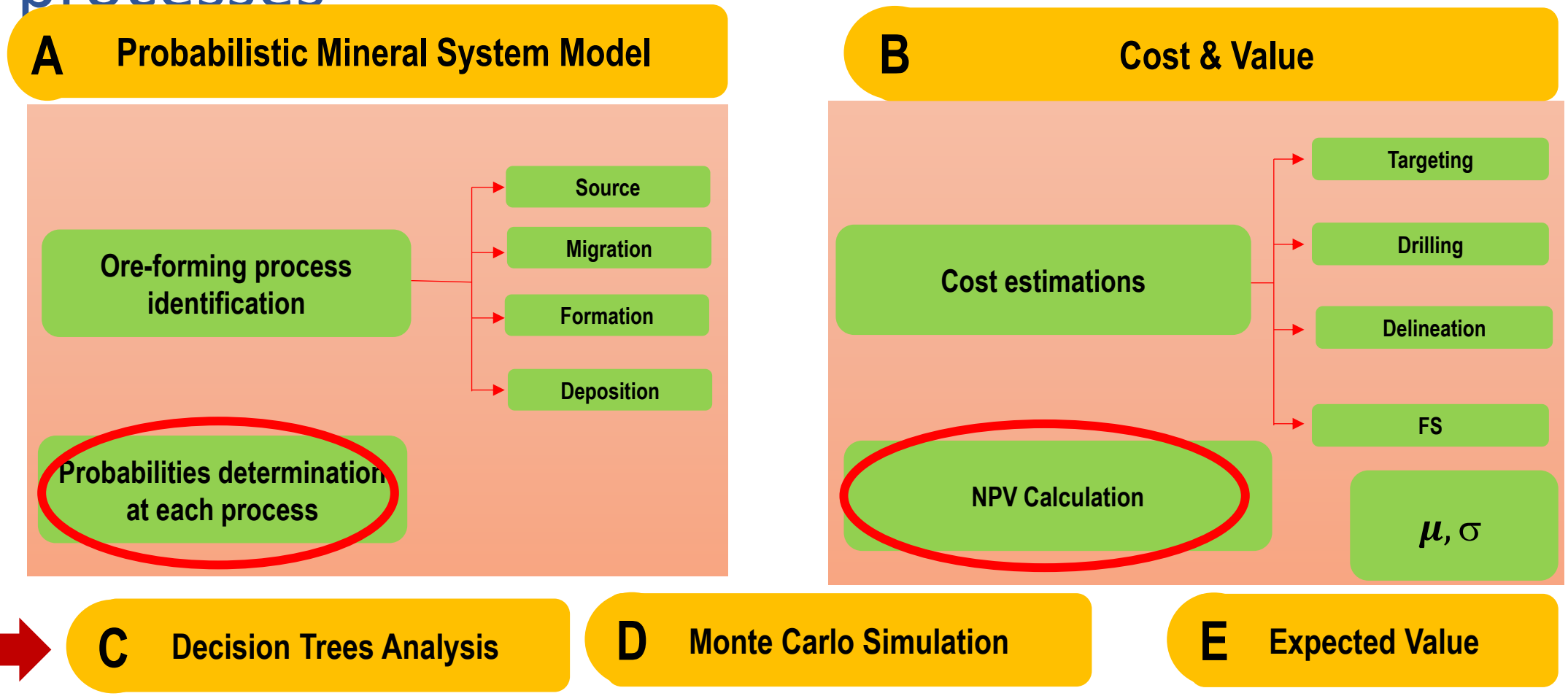
Expected Value (EV) computation processes



Sumber: Kreuzer, *et al*, 2008

The expected value (EV) method is expressed below (Faúndez, et al., 2020):

$$EV = (P_e \cdot P_g \cdot V) - C$$

P_e is exploration risks

P_g is geological uncertainty

V is potential value (using market or income approaches)

C is all exploration costs are accounted for according to IFRS 6

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A. Exploration risks

Parameter	Sub-Parameter	Weight
Technical Factor	- Geological knowledge of the exploration team	23%
	- Information	22%
Geopolitical Factor	-Ownership	16%
	- Envi/Community Risks	14%
	- Political Risks	13%
	- Access	12%
	Pexploration risk	

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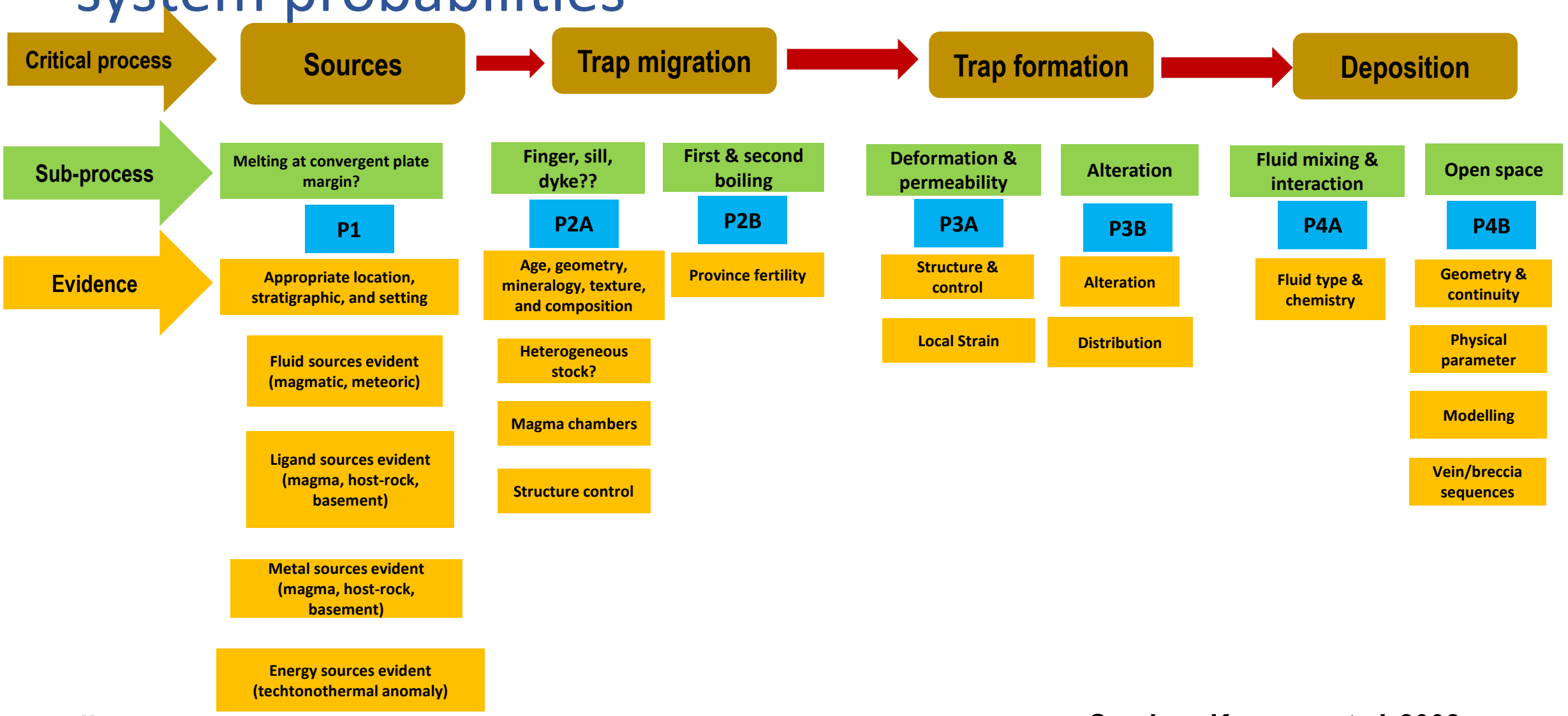
B. Geological Uncertainty - Mineral system probabilities



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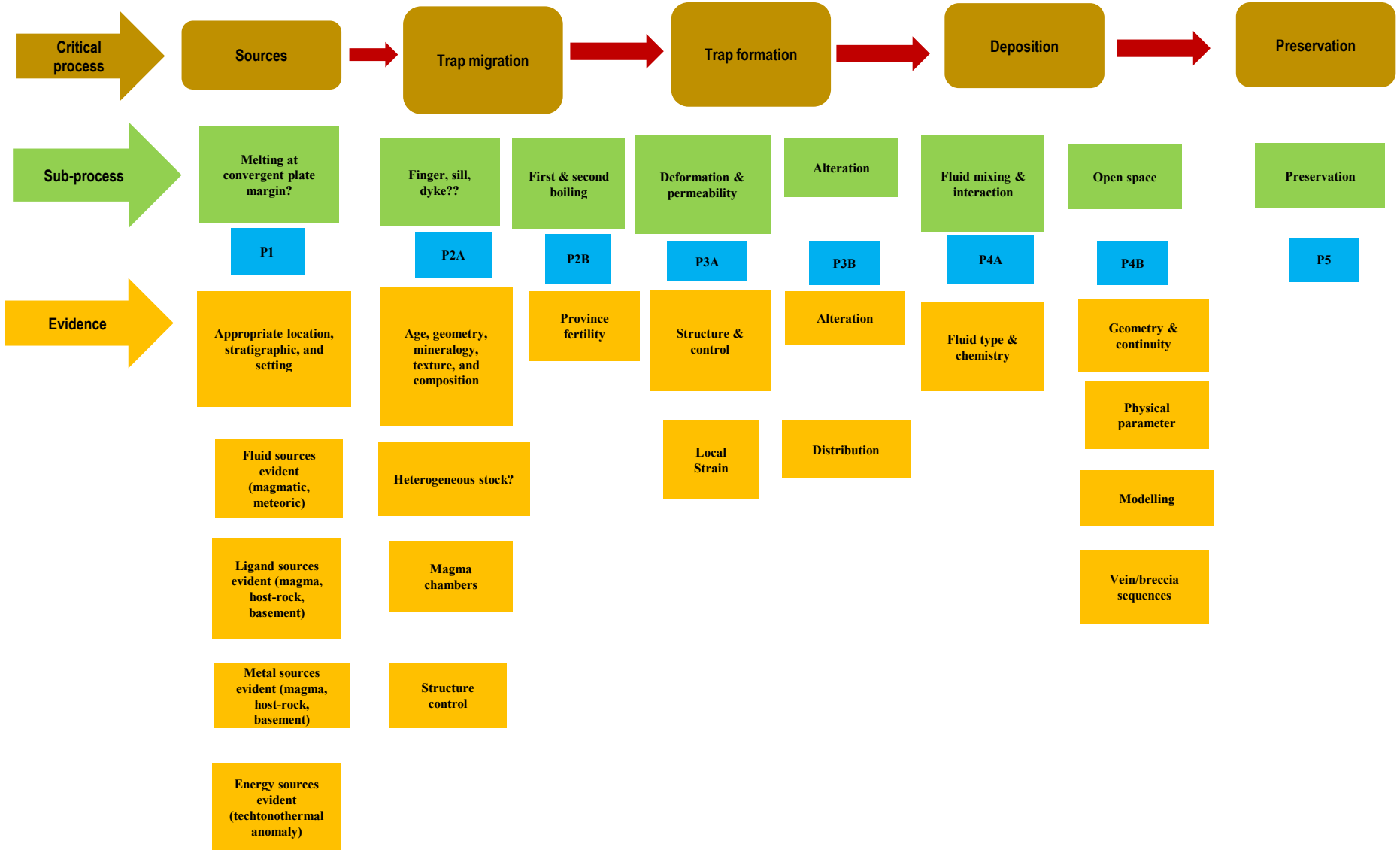
Sumber: Kreuzer, *et al*, 2008



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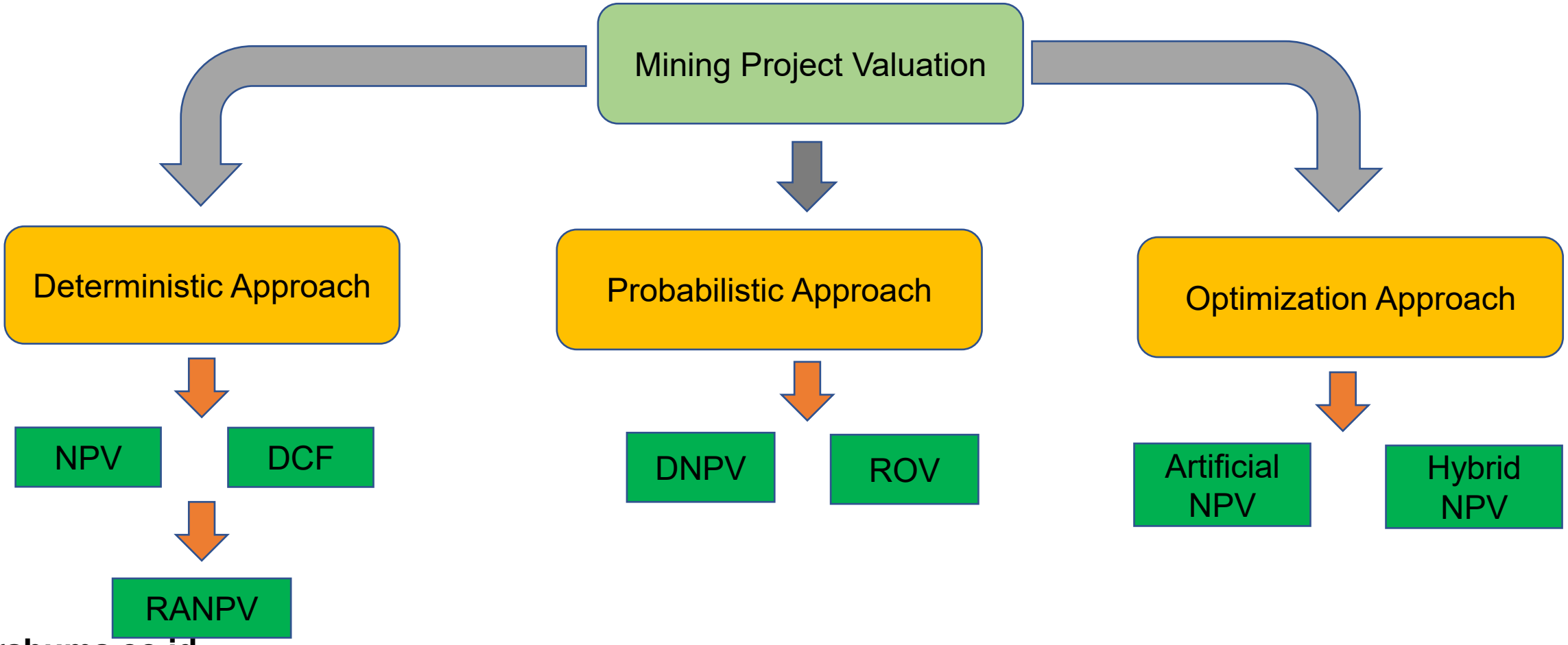
Sumber: Faundez *et al*, 2020

Valuation using the Income Approach - NPV



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2. NPV EVOLUTION - Traditional NPV & DCF

Single Inputs

REVENUE

OPEX

CAPEX

CASH FLOWS

Single Output

NPV

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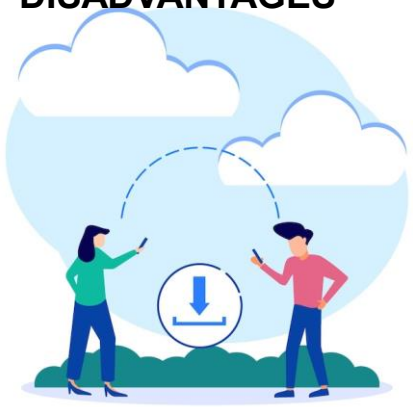
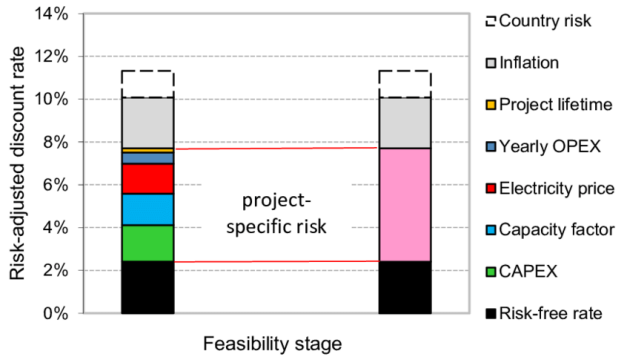
DISADVANTAGES



Future cash flows adjustment by a single factor

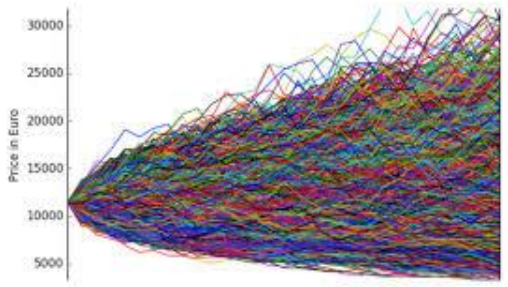
SOLUTION



METHODOLOGIES

RANPV

Growing exponentially with time



DNPV

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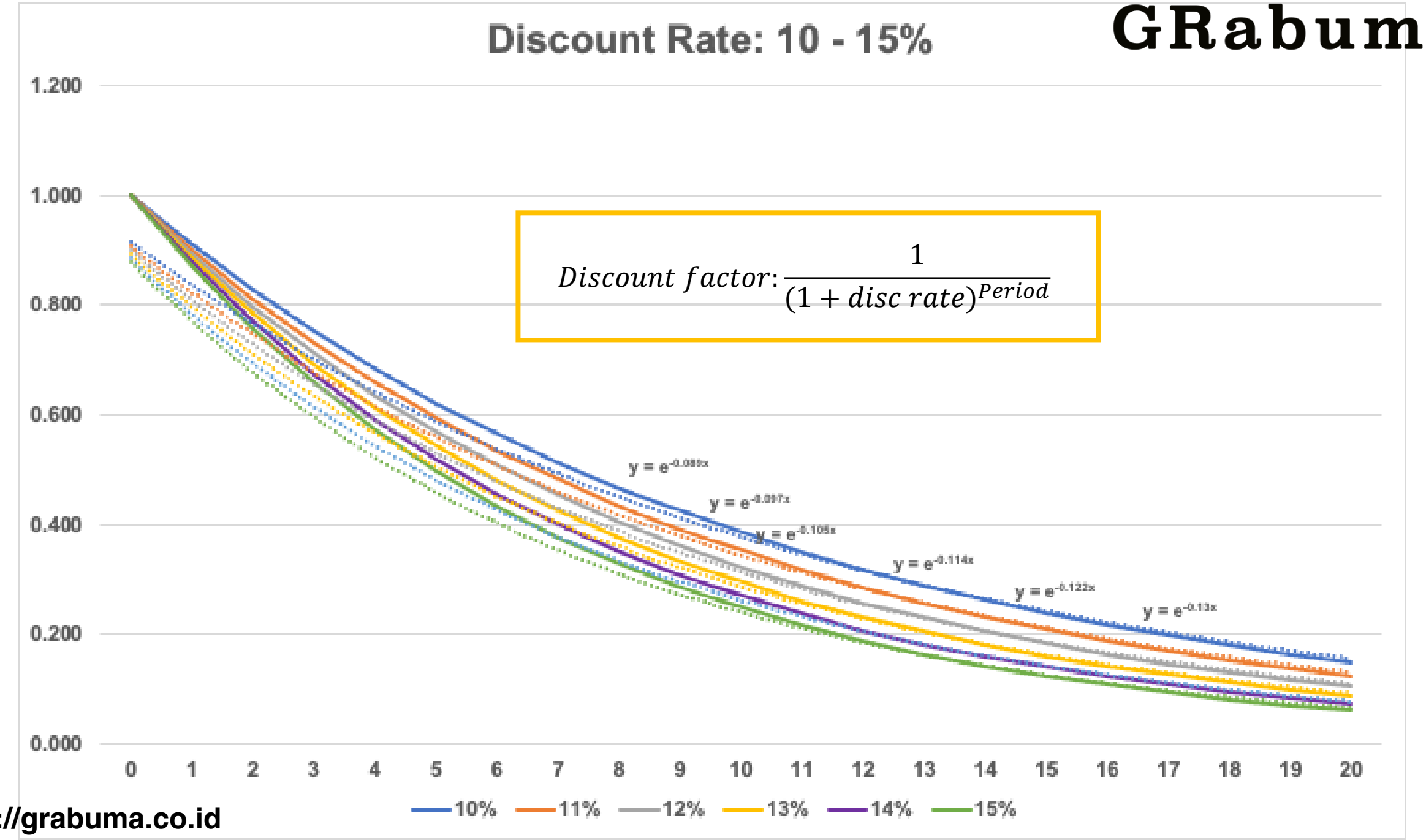
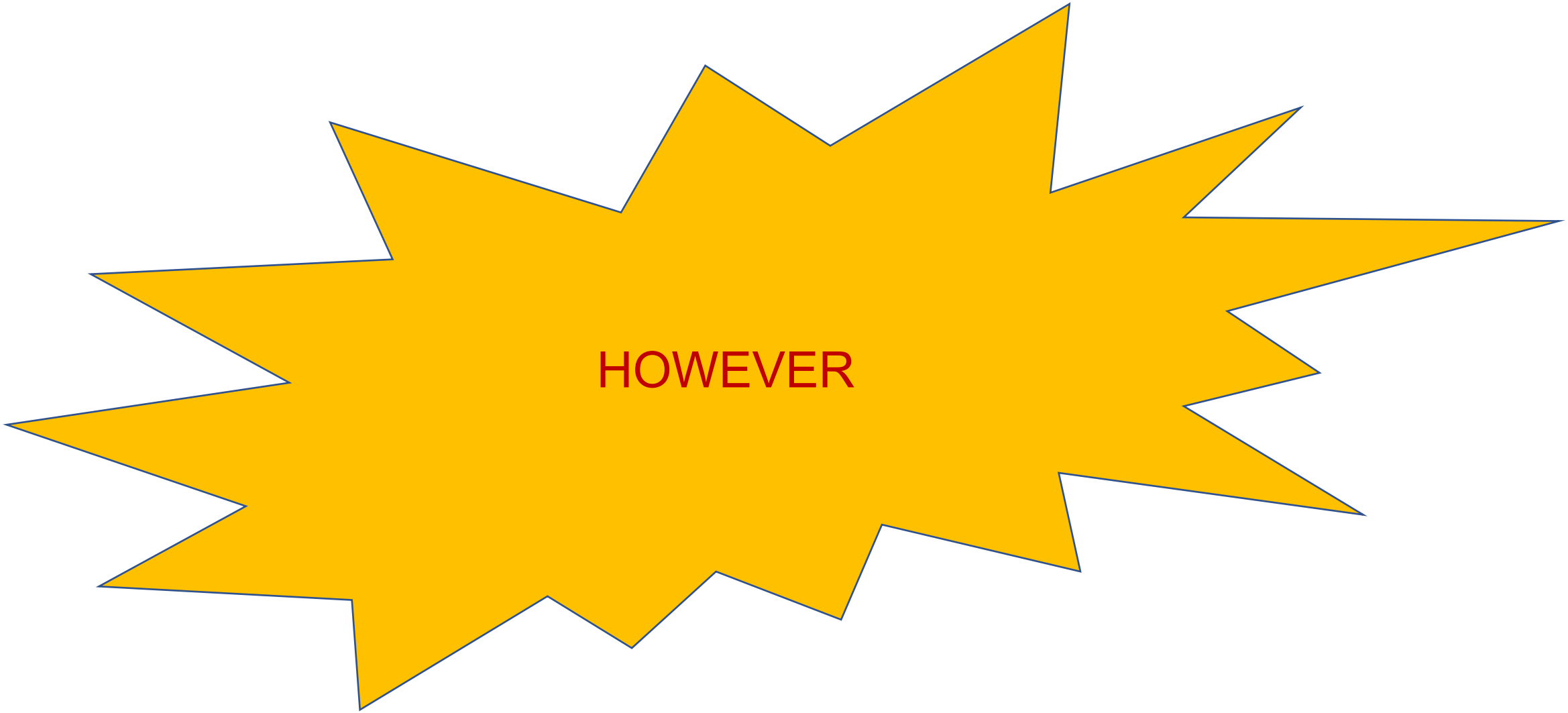
Discount Rate: 10 - 15%



$$Discount\ factor: \frac{1}{(1 + disc\ rate)^{Period}}$$


HOWEVER

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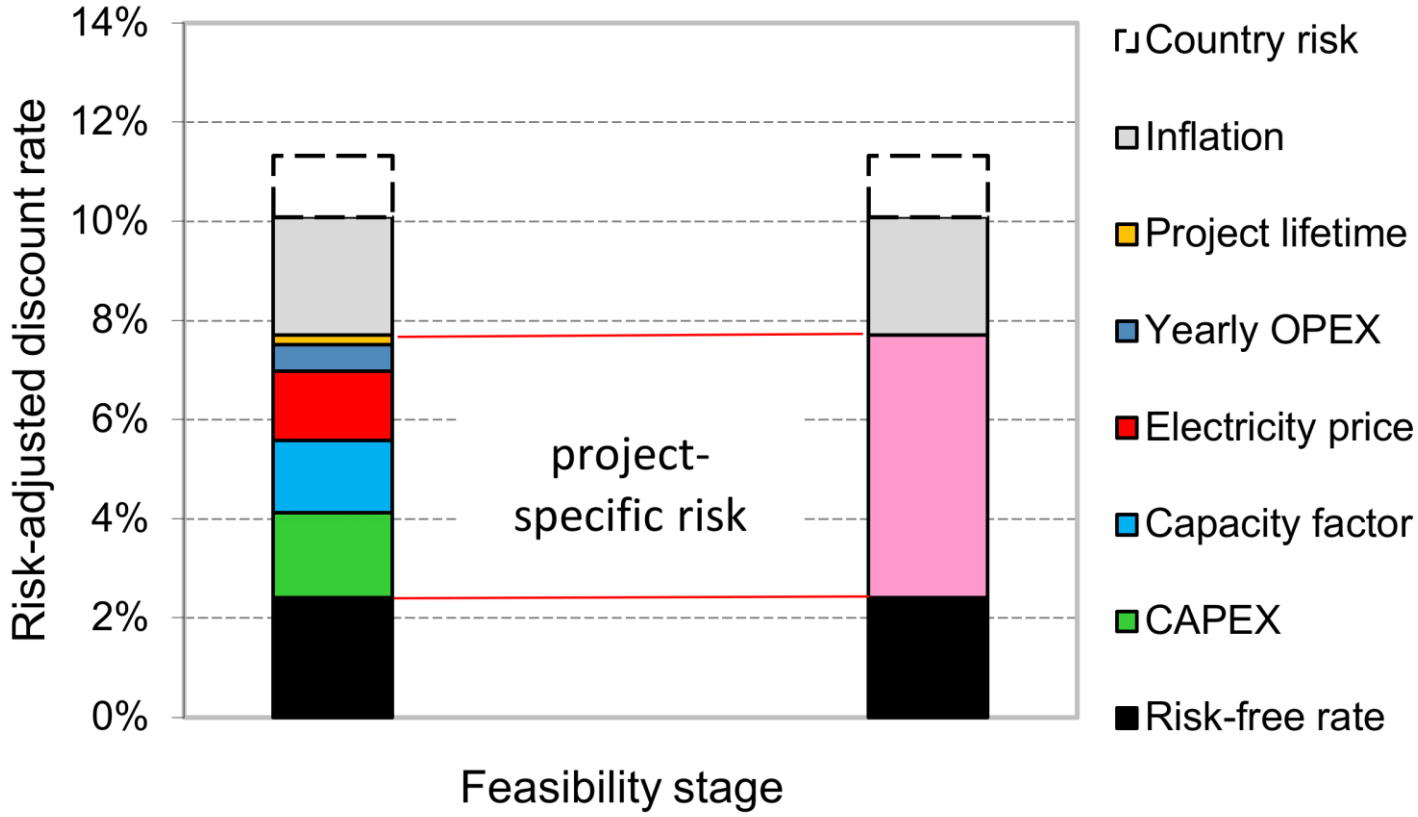
2.B. Risk-adjusted NPV

- ✓ Based on Risk-adjusted discount rate
- ✓ Discount rate has involved the additional risks (level of project, country risks and commodities)



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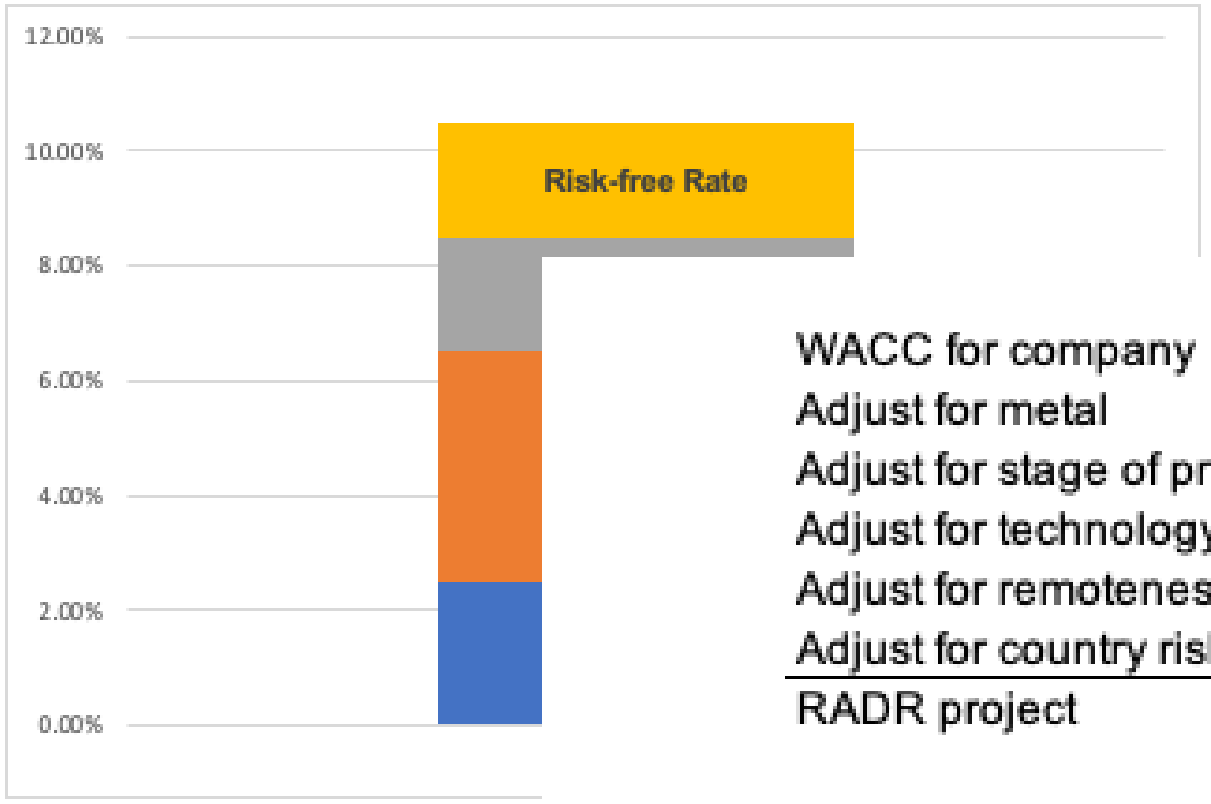
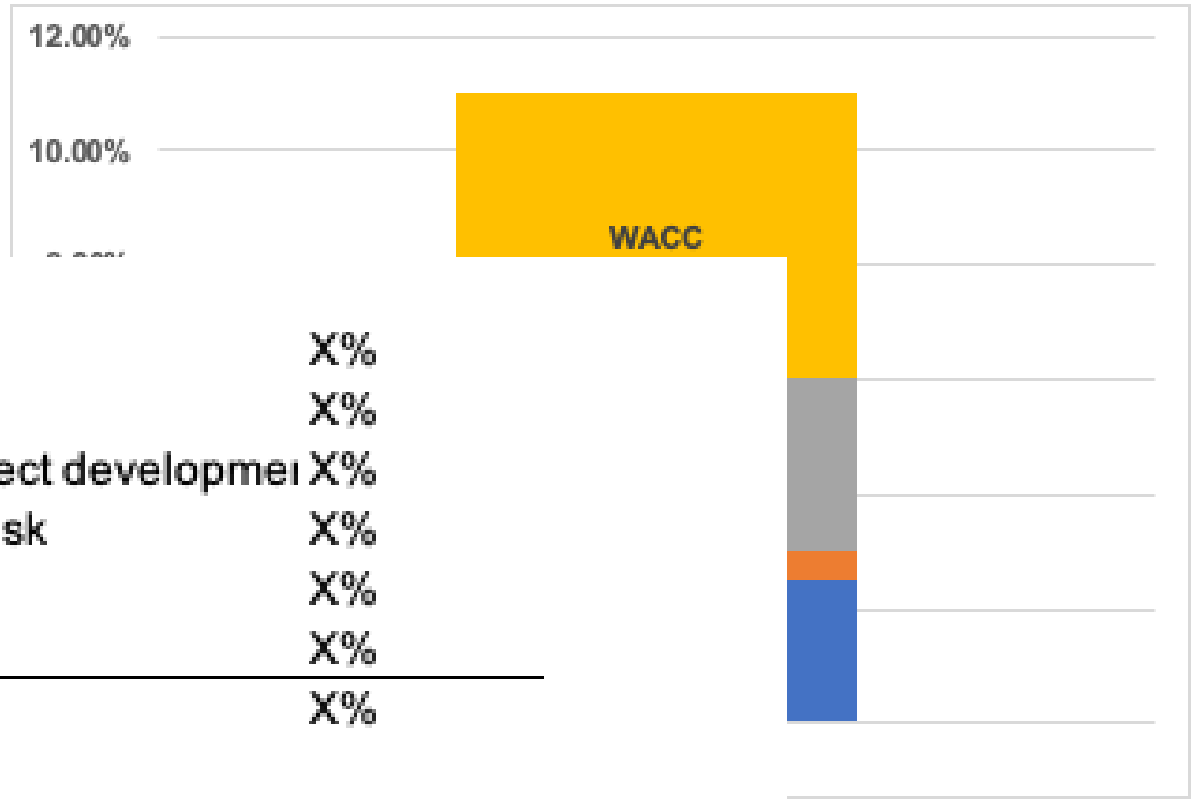
RADR Build-up using WACC

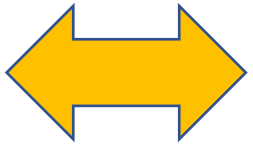
$$RADR = WACC + (X_r + U_t)$$



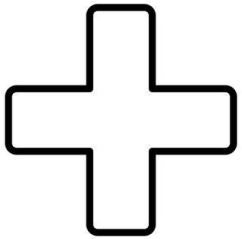
WACC for company	X%
Adjust for metal	X%
Adjust for stage of project developmei	X%
Adjust for technology risk	X%
Adjust for remoteness	X%
Adjust for country risk	X%
RADR project	X%



2.C. Decoupled NPV



Certainty Equiv Methods



Financial Risk

Human Resources Risk

Natural Risk

Technical Risk

Environmental/Political Risk

Decoupled NPV

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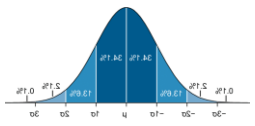
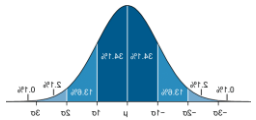
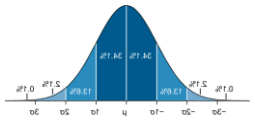
Random & Probabilistic Inputs



REVENUE

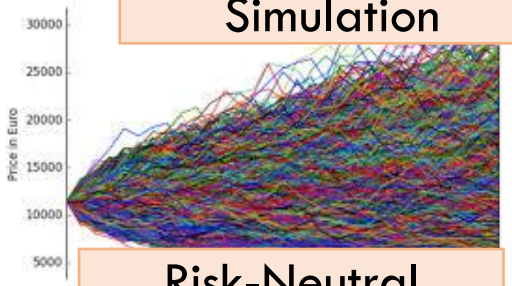


OPEX



CAPEX

Monte Carlo Simulation

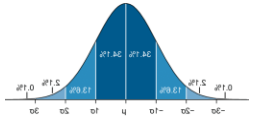


Risk-Neutral Situation

$$= \left(\frac{P_{50} - P_{79}}{P_{50}}\right) \text{ x (value} < P_{50})$$

CASH FLOWS

Probabilistic Output



NPV

RADR

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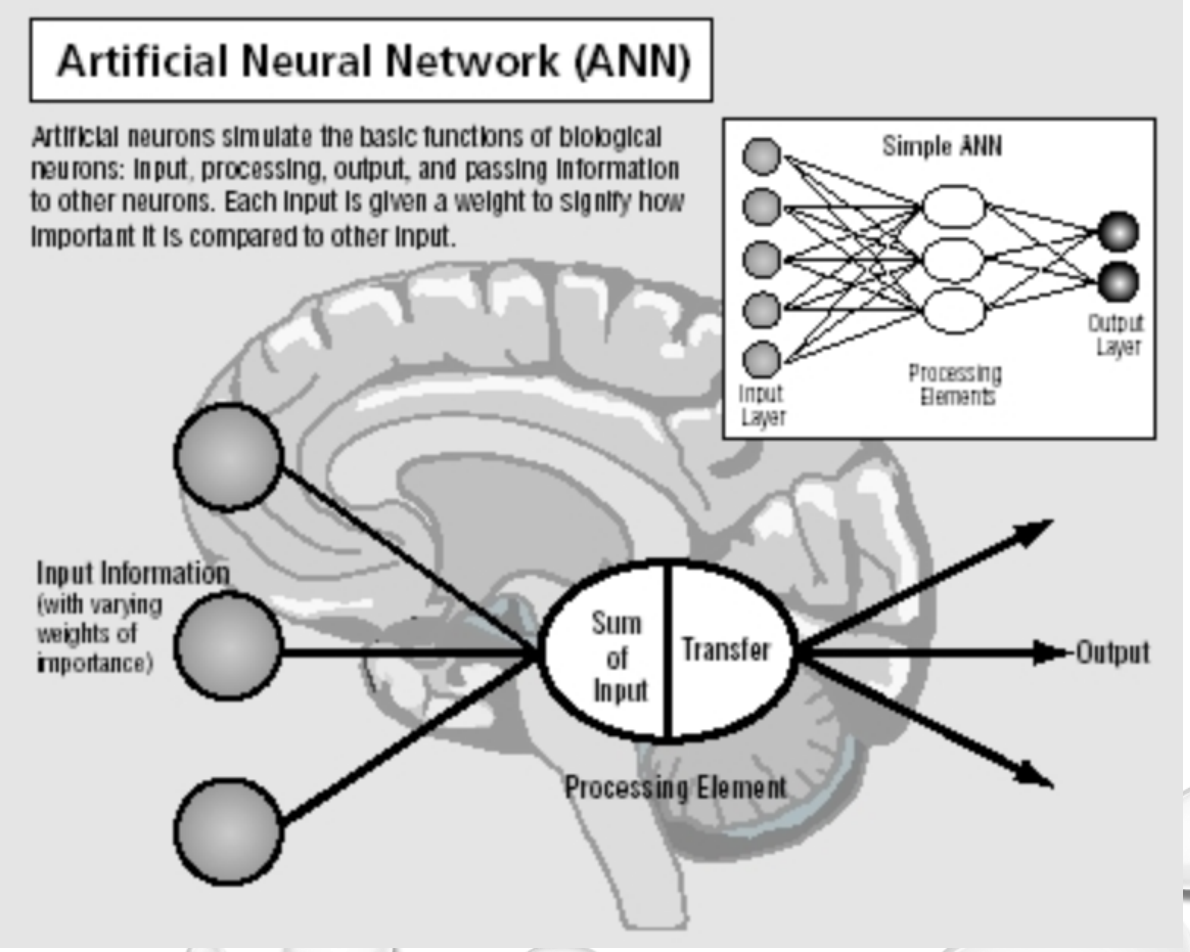
3. ARTIFICIAL NEURAL NETWORK (ANN)

- ✓ Modelled based on the human brain process
- ✓ Recognize patterns from data sources
- ✓ Analysing and simulating to solve the complex data sources
- ✓ Containing Input layer, hidden layer and output layer



- ✓ The architecture of an artificial neural network (ANN) consists of neurons organized into an input layer, one or more hidden layers, and an output layer
- ✓ The data from the input layer is transferred to the hidden layers for processing.
- ✓ Each neuron in the input layer has a constant bias value
- ✓ The processed data is then passed to the output layer, where the output of each neuron is calculated as the total value of the input weights, adjusted by activation functions (Ketkar, 2017)
- ✓ The Artificial Neural Network (ANN) model is capable of handling non-linear data and can effectively model the complex relationships between input and output data
- ✓ However, traditional ANNs often fall short in achieving true optimization, as they adjust weights solely based on a learning coefficient
- ✓ To address this limitation, it is essential to incorporate biologically inspired algorithms, such as the BA, to enhance optimization processes (Hannan, et al., 2014).

Simple Architecture of Artificial Neural Network (ANN)

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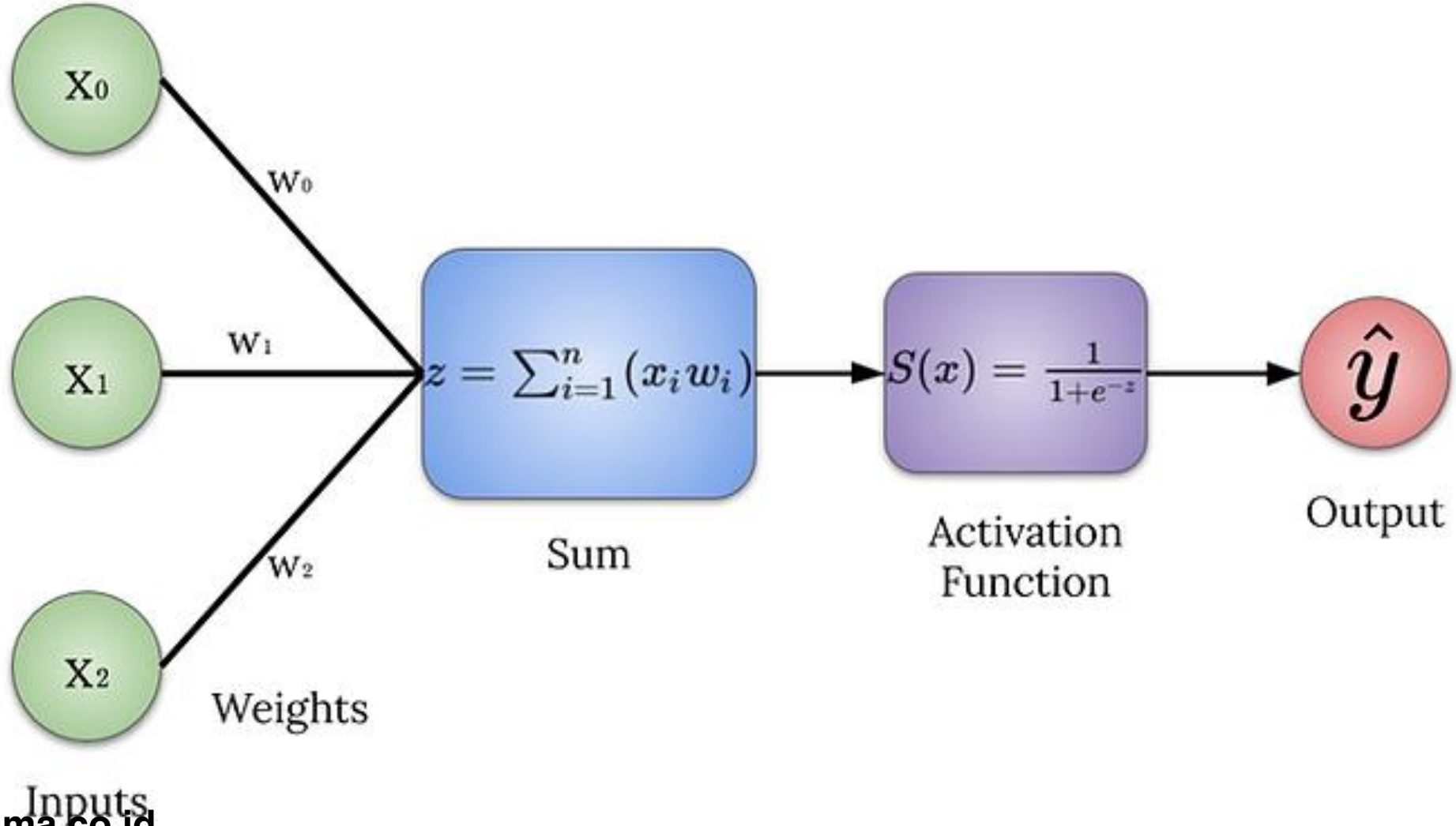

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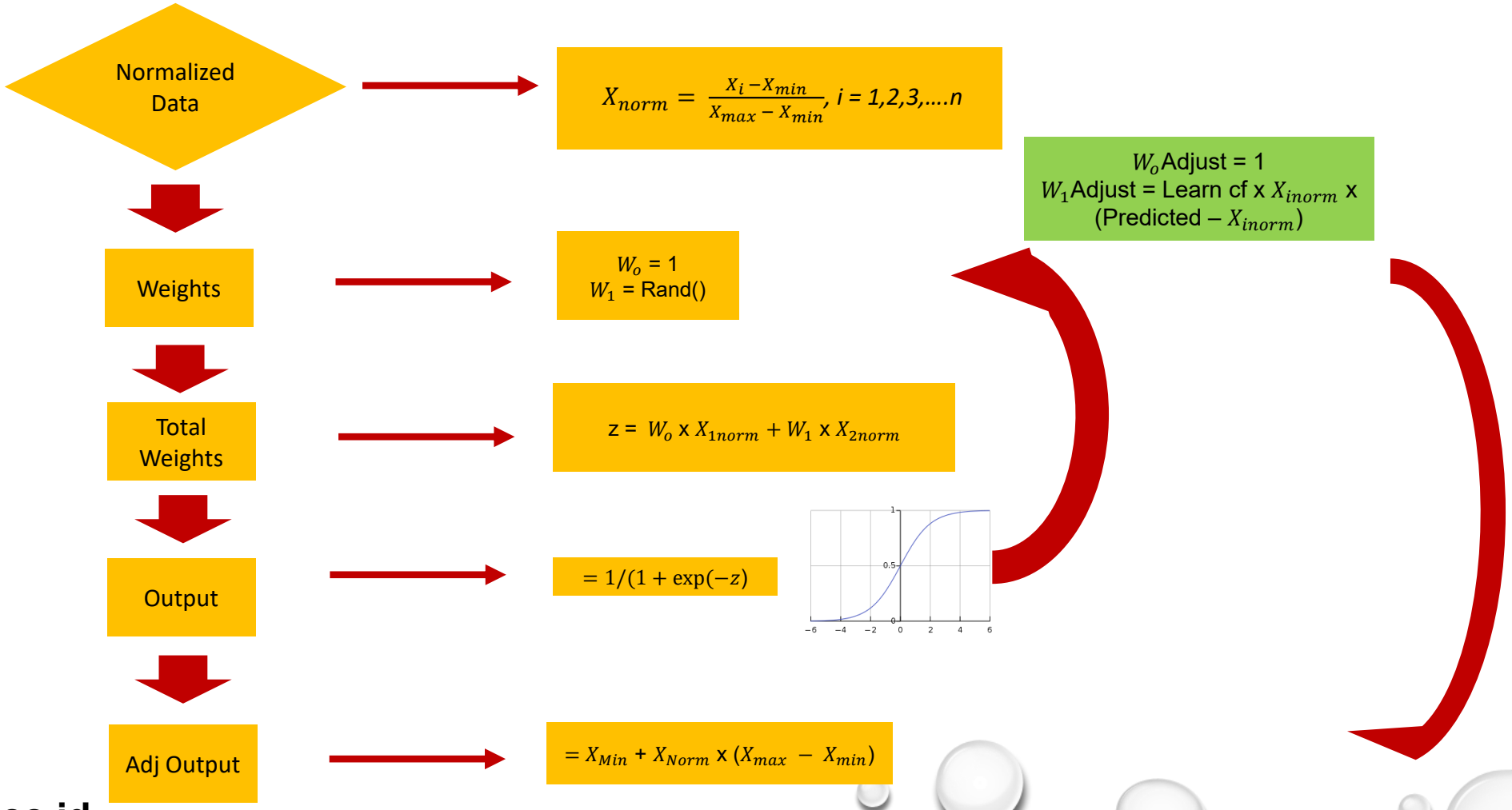
Flowchart of the Artificial Neural Networks (ANN)



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The weakness of AI

- ✓ Complex, high cost and time-consuming
- ✓ Fixed standard
- ✓ No improvements

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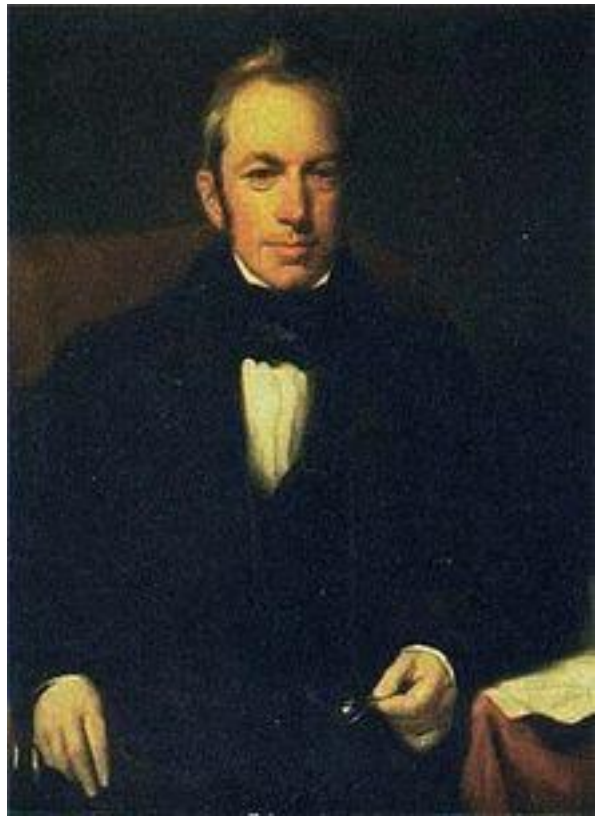
4. METAHEURISTICS MODELS

Metal Price Forecasting Evolution

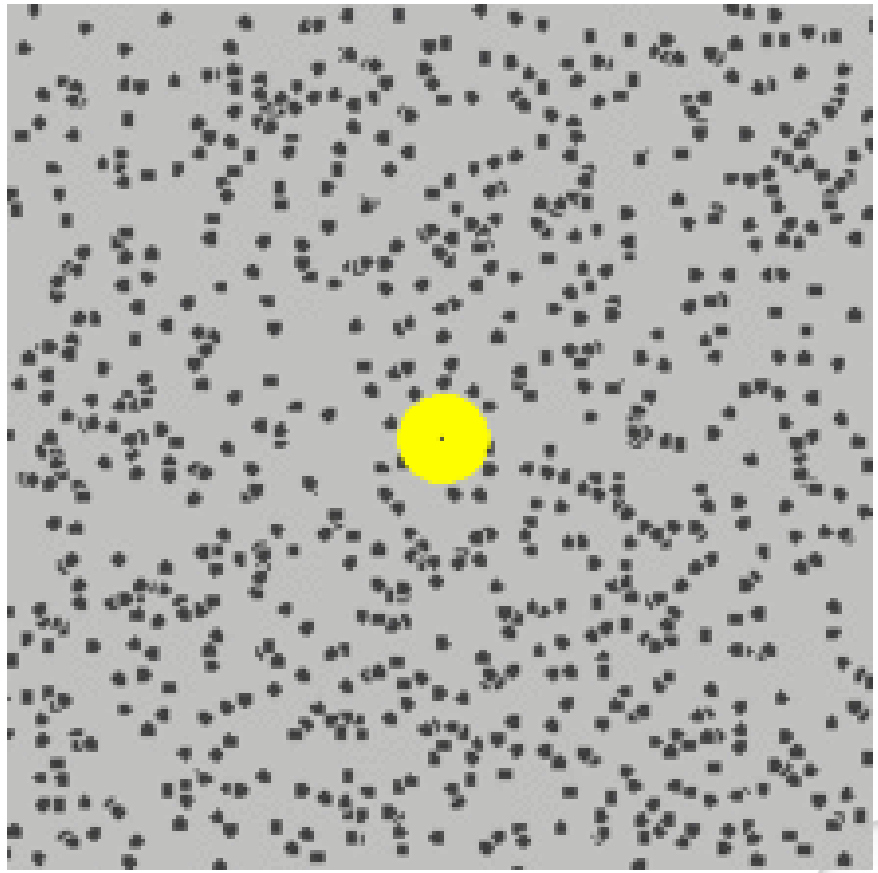
Solving complex problems using an optimized solution based on the search strategy

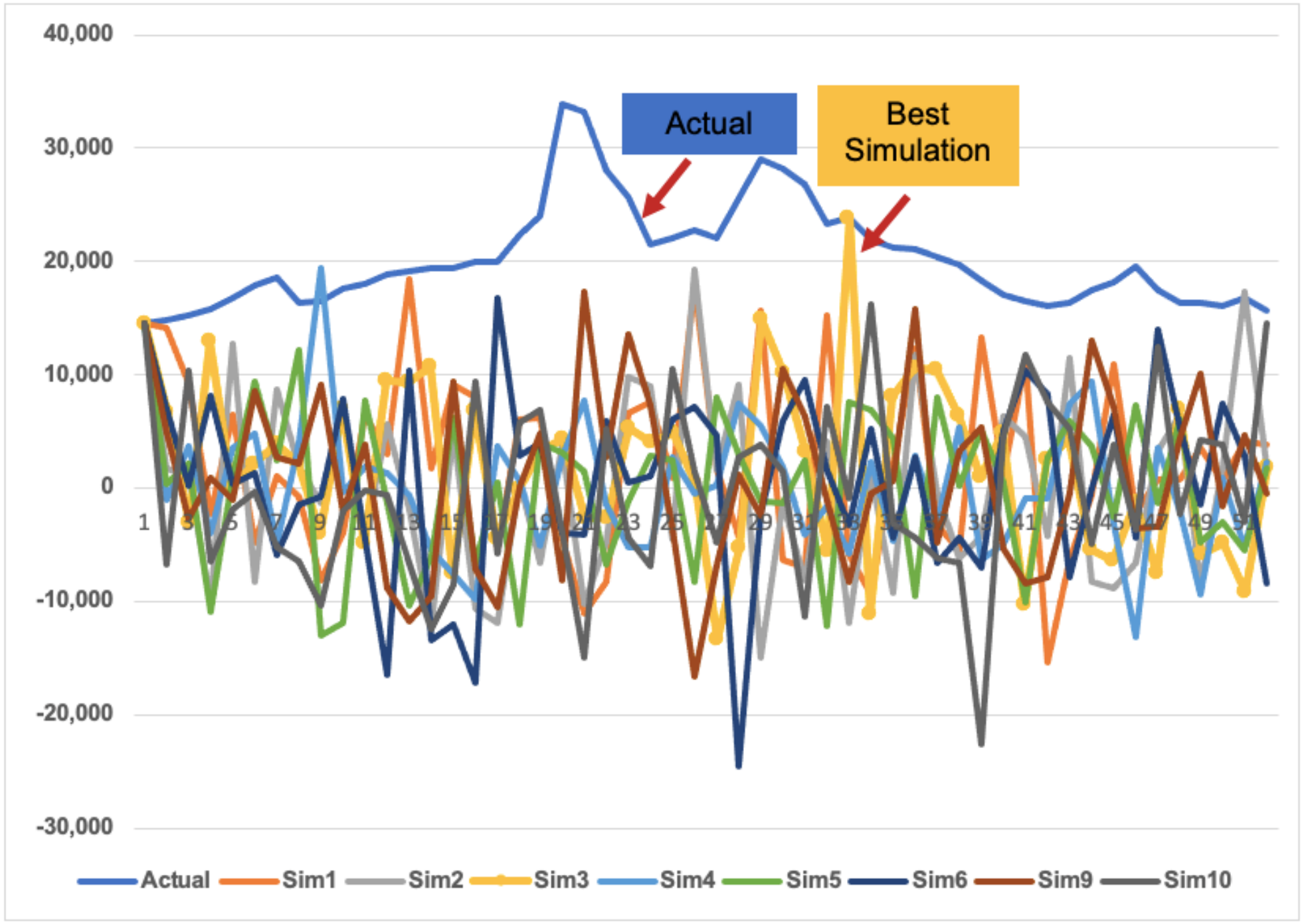
How to optimize random motion



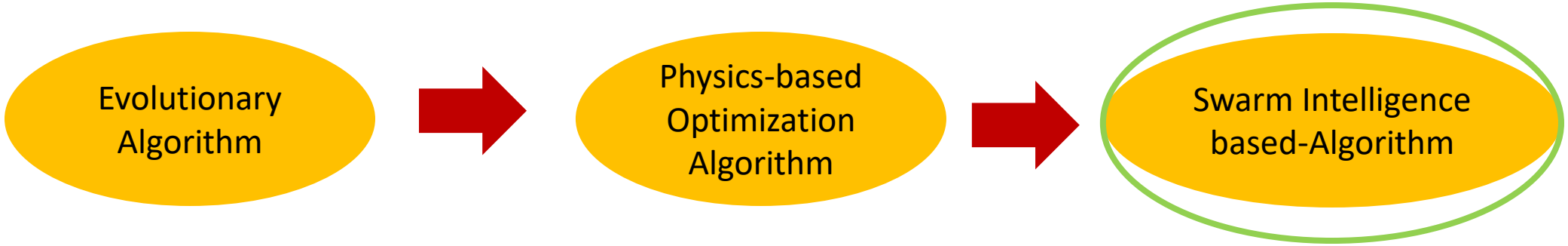
Robert Brown (1773 – 1858)

- ✓ Introduced by a Scottish Botanist in 1827
- ✓ Random pollen motion in liquid is called Brownian motion




40,000
30,000
20,000
10,000
0
-10,000
-20,000
-30,000
Actual
Best Simulation
Actual
Sim1
Sim2
Sim3
Sim4
Sim5
Sim6
Sim9
Sim10

Metaheuristic Optimization Approaches



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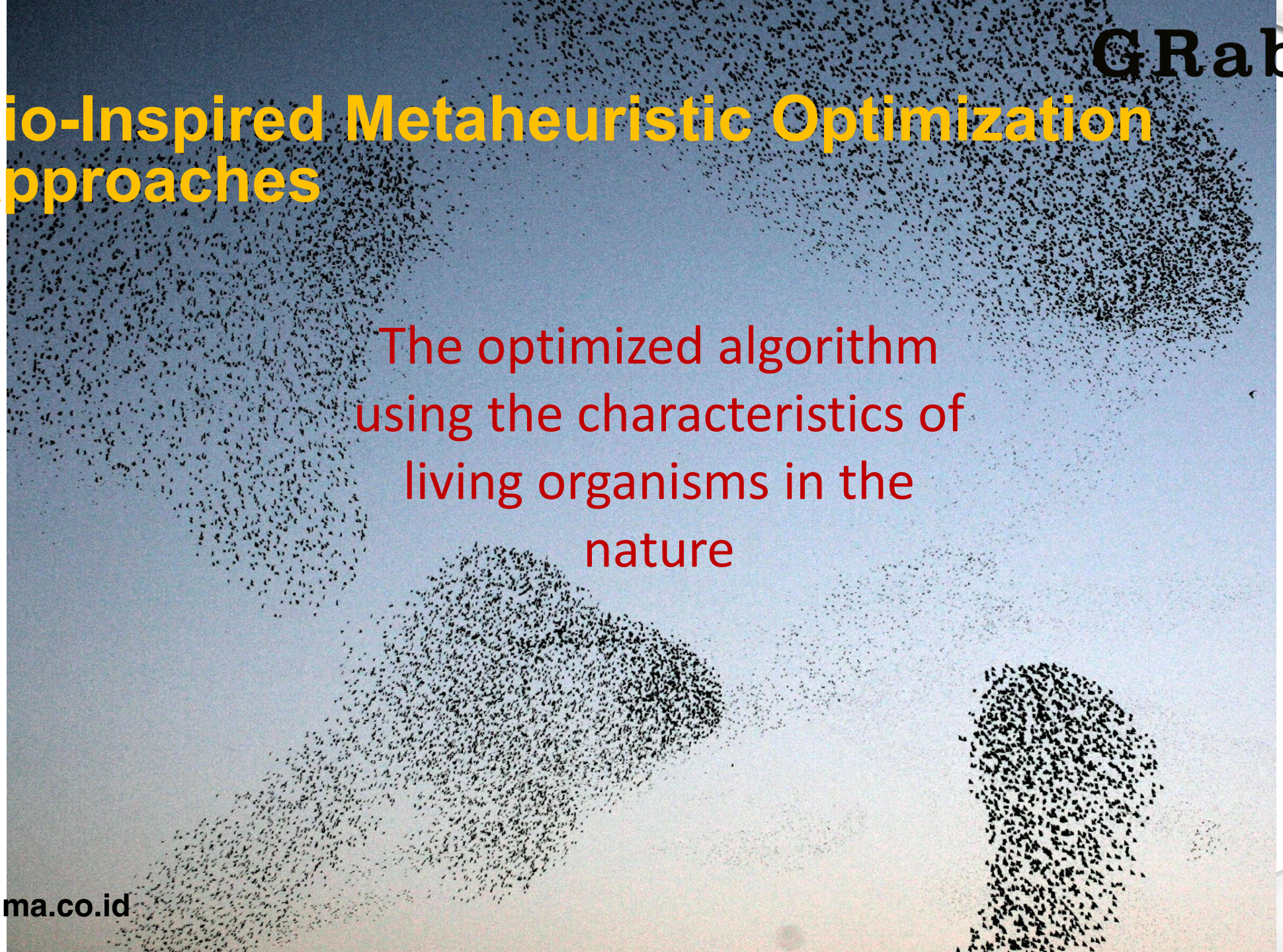
Bio-Inspired Metaheuristic Optimization Approaches

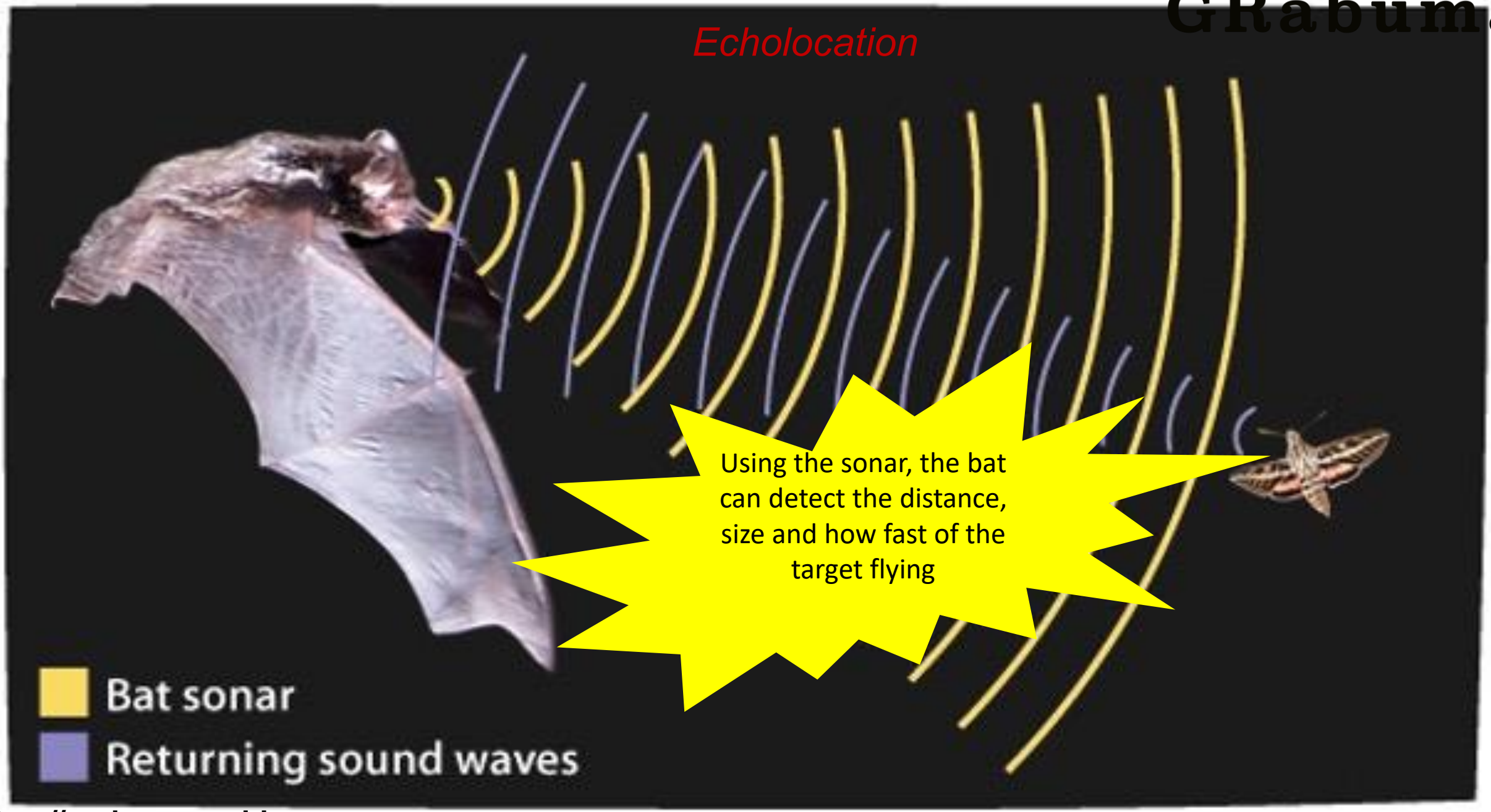


The optimized algorithm using the characteristics of living organisms in the nature

Bat Algorithm (BA)

- ✓ Consisting of 1,000 species of Bats
- ✓ Flying mammals (small to medium)
- ✓ Length of 2.2 to 11cm, weight of 3 – 150g, and wing span of 25cm
- ✓ Introduced by Xin-She Yang in 2010
- ✓ Metaheuristic algorithm for global optimization
- ✓ Inspired by the echolocation behavior, pulse rate and loudness
- ✓ Using **echolocation** of **microbats**

Echolocation



Parameters in Bat Algorithm (BA)

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Position (x_i)

Velocity (v_i)

Frequency (f_i)

Pulse Rate (r_i)

Loudness (A_i)

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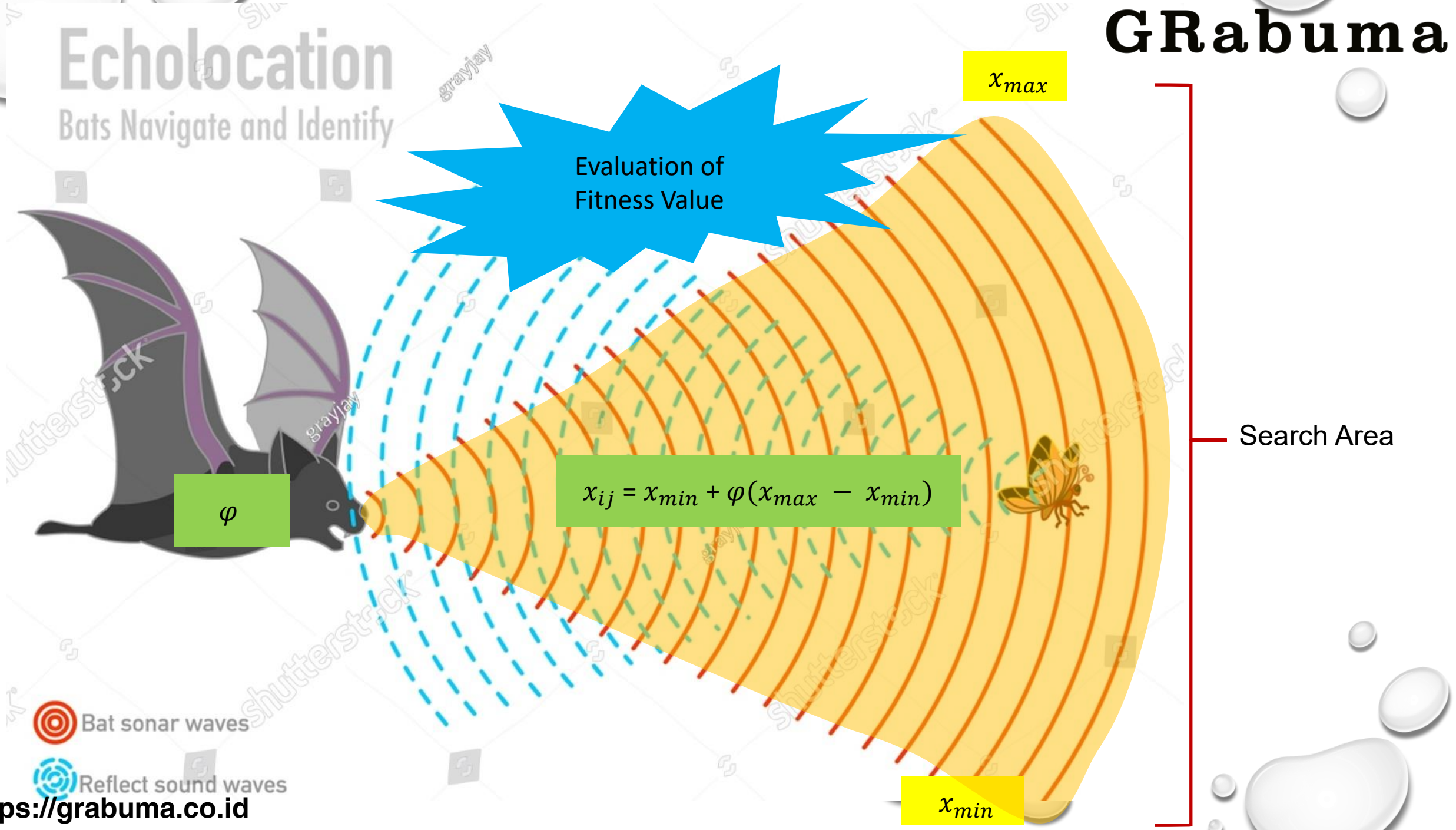
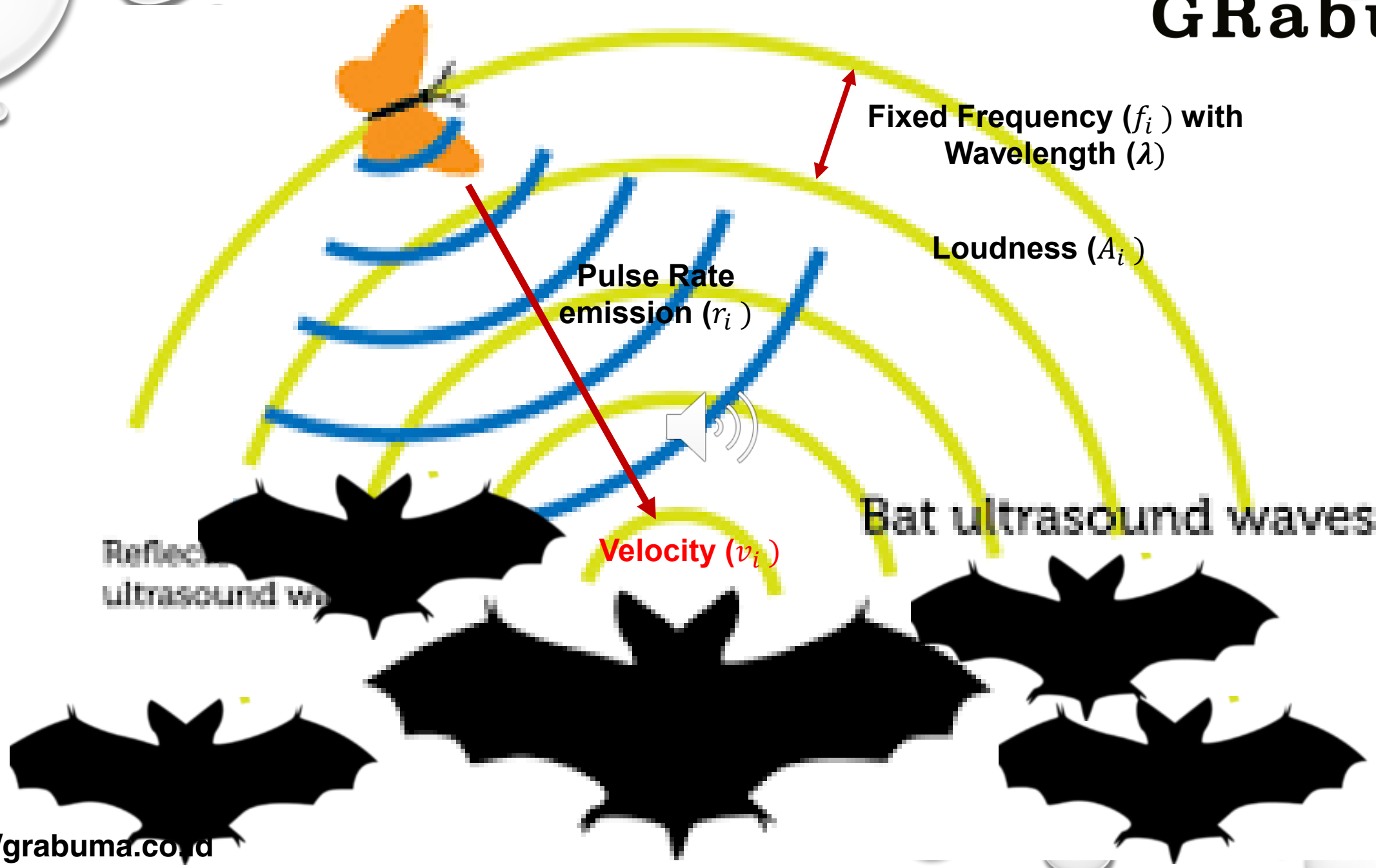
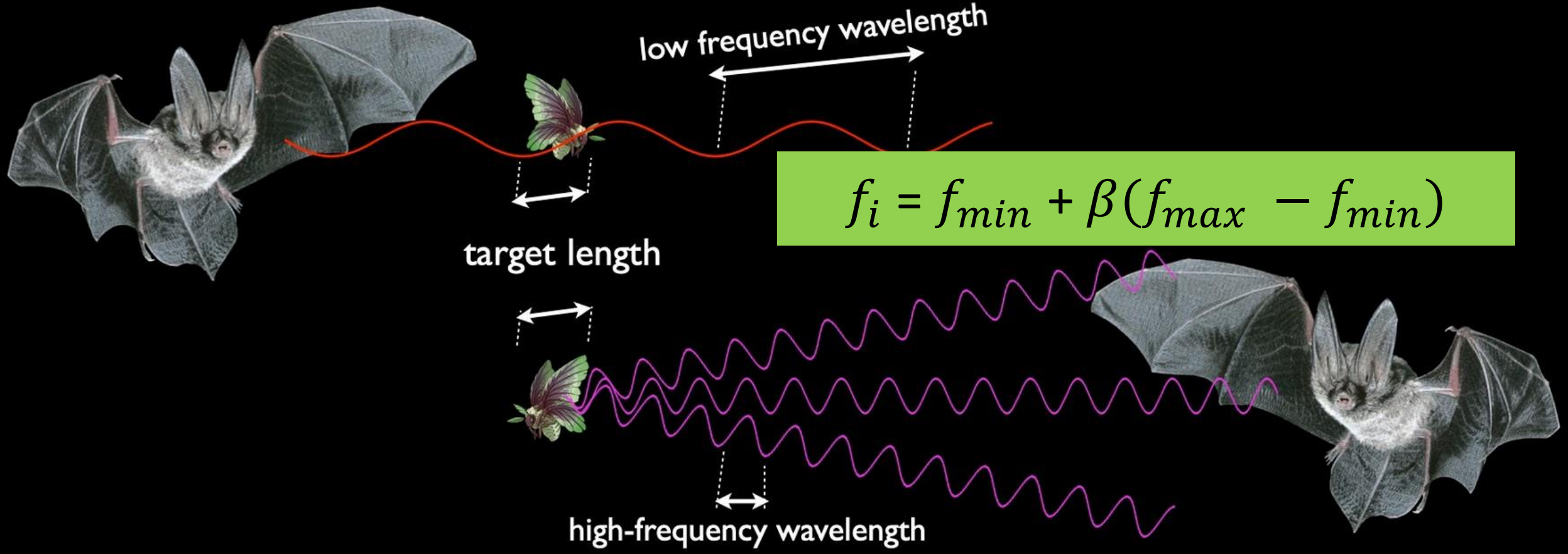

Echolocation
Bats Navigate and Identify
Evaluation of Fitness Value
x_{max}
x_{min}
φ
$x_{ij} = x_{min} + \varphi(x_{max} - x_{min})$
Search Area
Bat sonar waves
Reflect sound waves


Fixed Frequency (f_i) with Wavelength (λ)
Loudness (A_i)
Pulse Rate emission (r_i)
Velocity (v_i)
Bat ultrasound waves

A wavelength more than twice the length of a target will pass around an object and not return to the bat.



$$f_i = f_{min} + \beta(f_{max} - f_{min})$$

But a sound with a wavelength that is less than twice the length of a target will generate an echo and bounce back to the bat.

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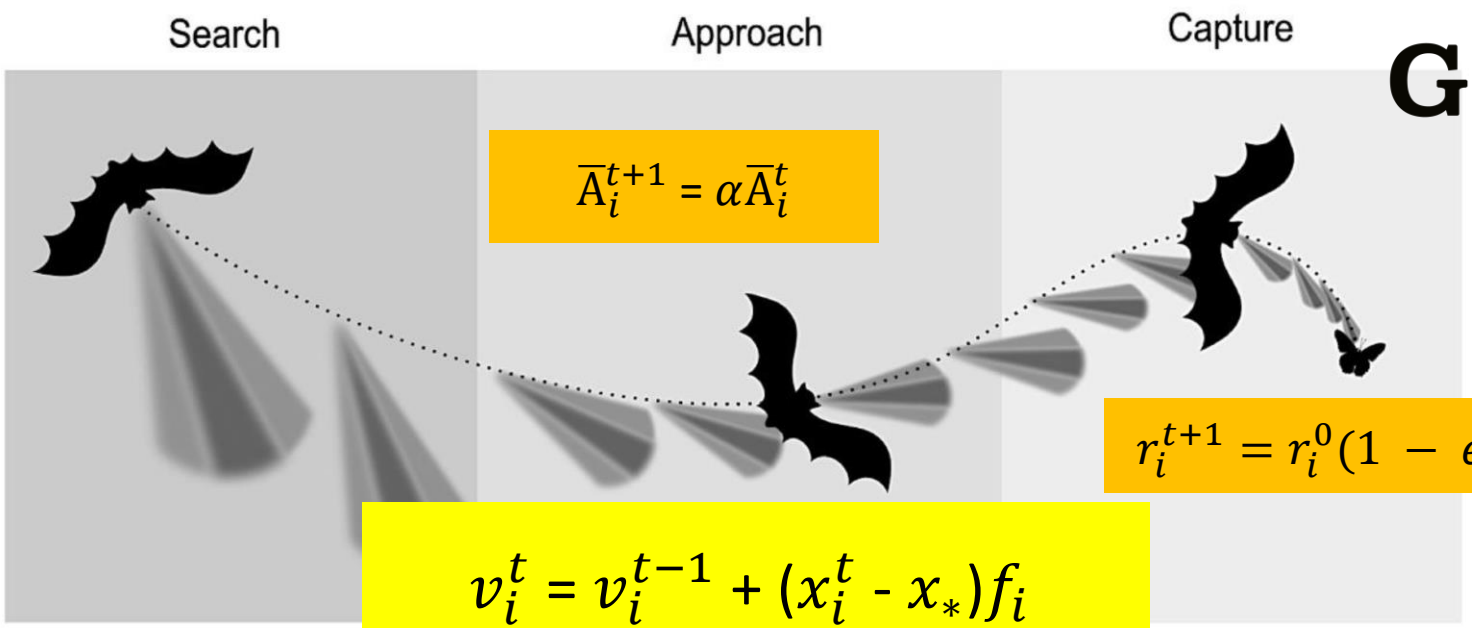


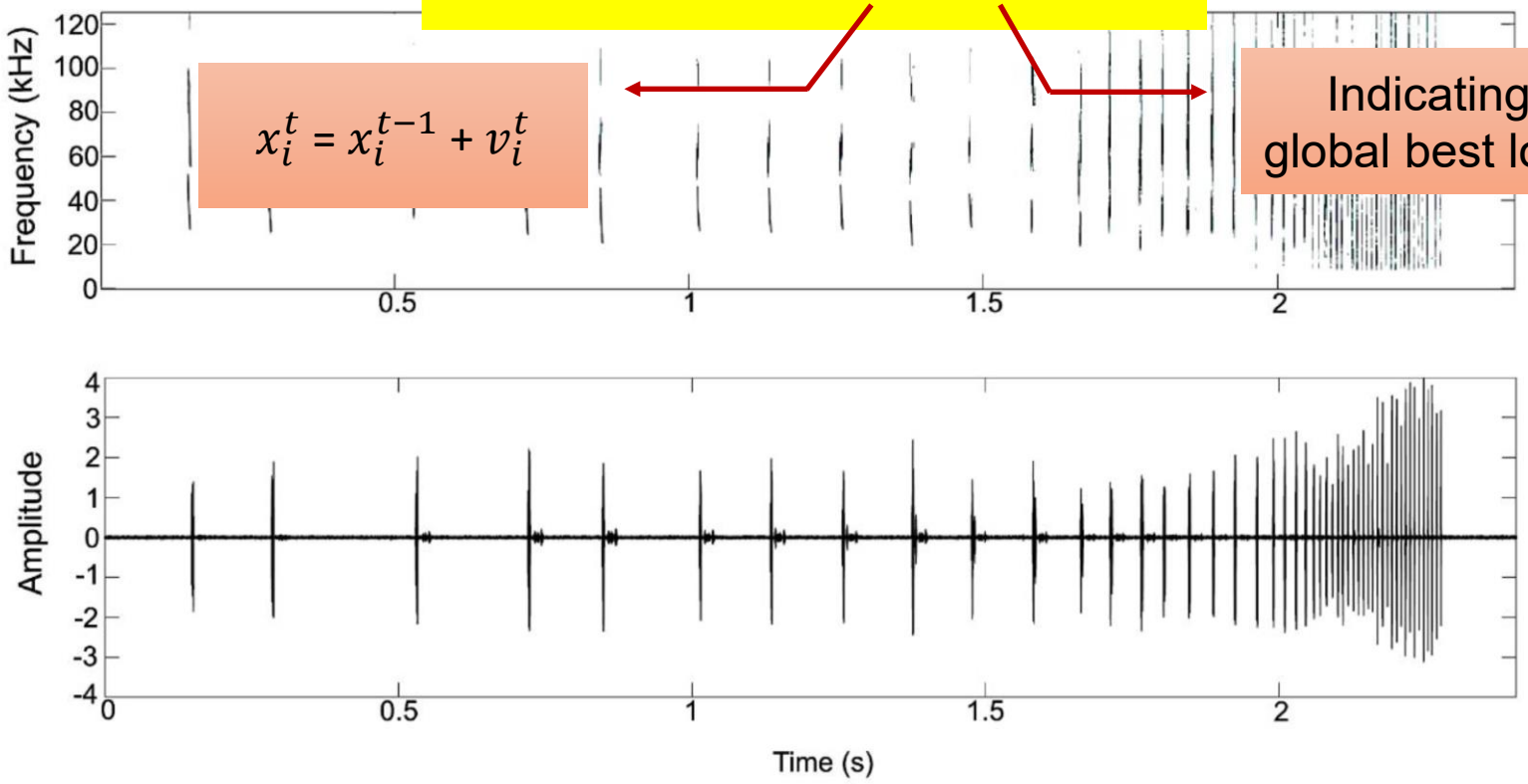
$$\overline{A}_i^{t+1} = \alpha \overline{A}_i^t$$

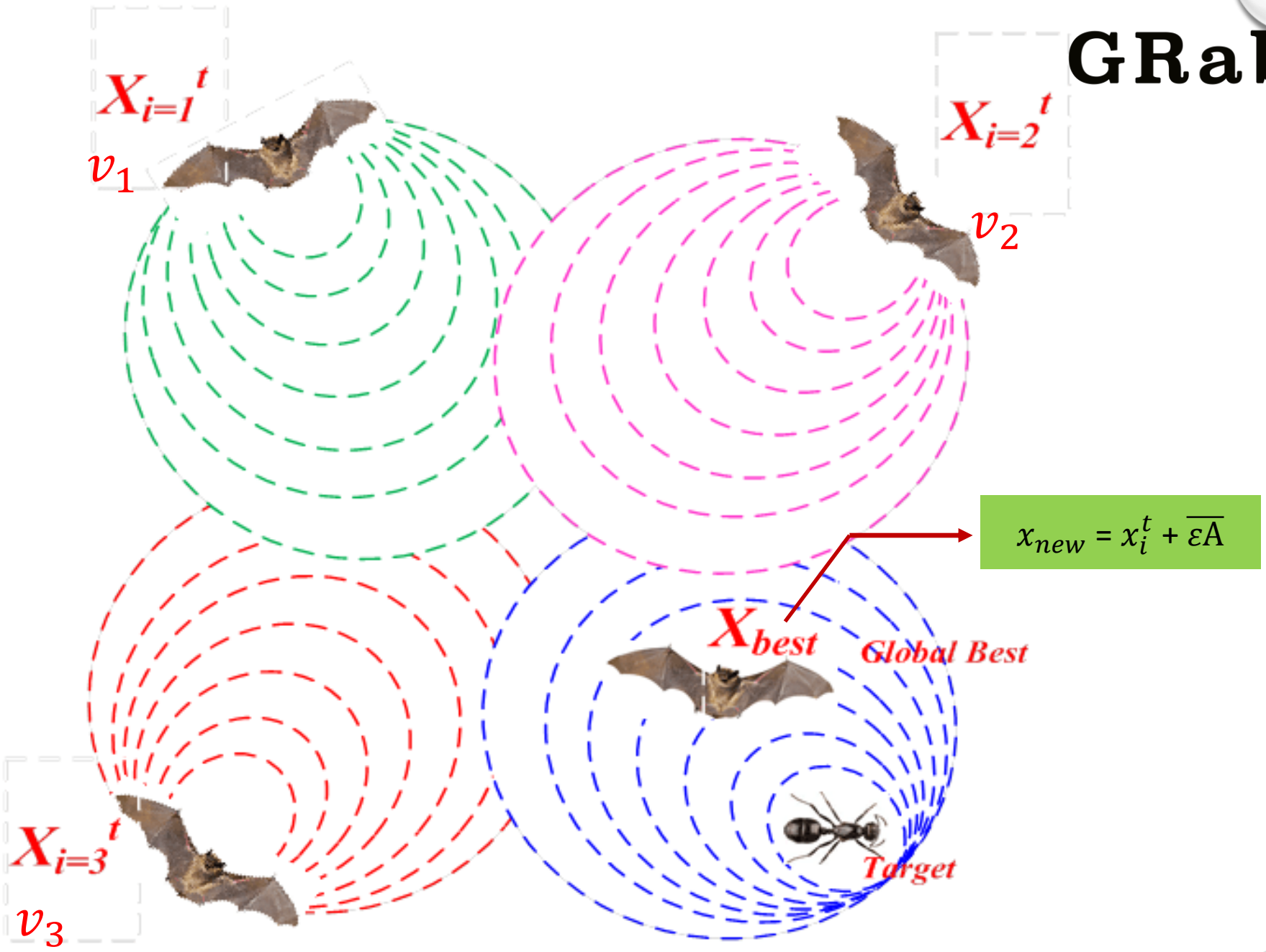
$$r_i^{t+1} = r_i^0(1 - e^{-\gamma t})$$

$$v_i^t = v_i^{t-1} + (x_i^t - x_*)f_i$$

$$x_i^t = x_i^{t-1} + v_i^t$$

Indicating the global best location




$X_{i=1}{}^{t}$
v_1
$X_{i=2}{}^{t}$
v_2
$x_{new} = x_i^t + \overline{\varepsilon A}$
X_{best}
Global Best
Target
$X_{i=3}{}^{t}$
v_3

Flowchart of Bat Algorithm

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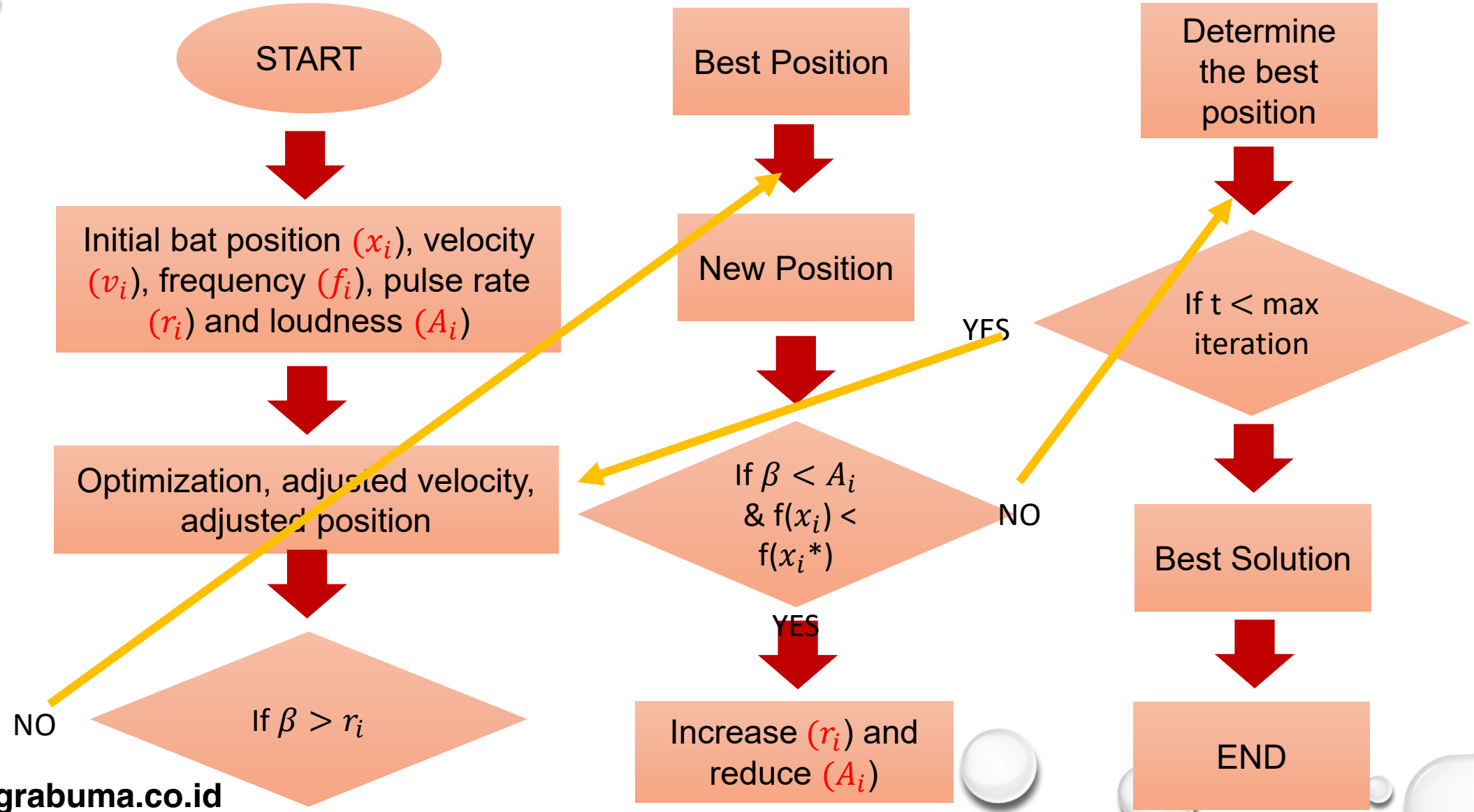

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Bat Algorithm Parameters

No	Parameter	Value	Remarks
1	Population Size	- Ranging from 10 to 40	Large population size increases the running of the process
2	Loudness & Pulse Rate	- Ranging from 0 to 1	Updated each iteration Processes
3	Frequency & Velocity	- Velocity ranges from 0 to 1	- Frequency represents the best location - Flying with velocity - Affected by random frequency

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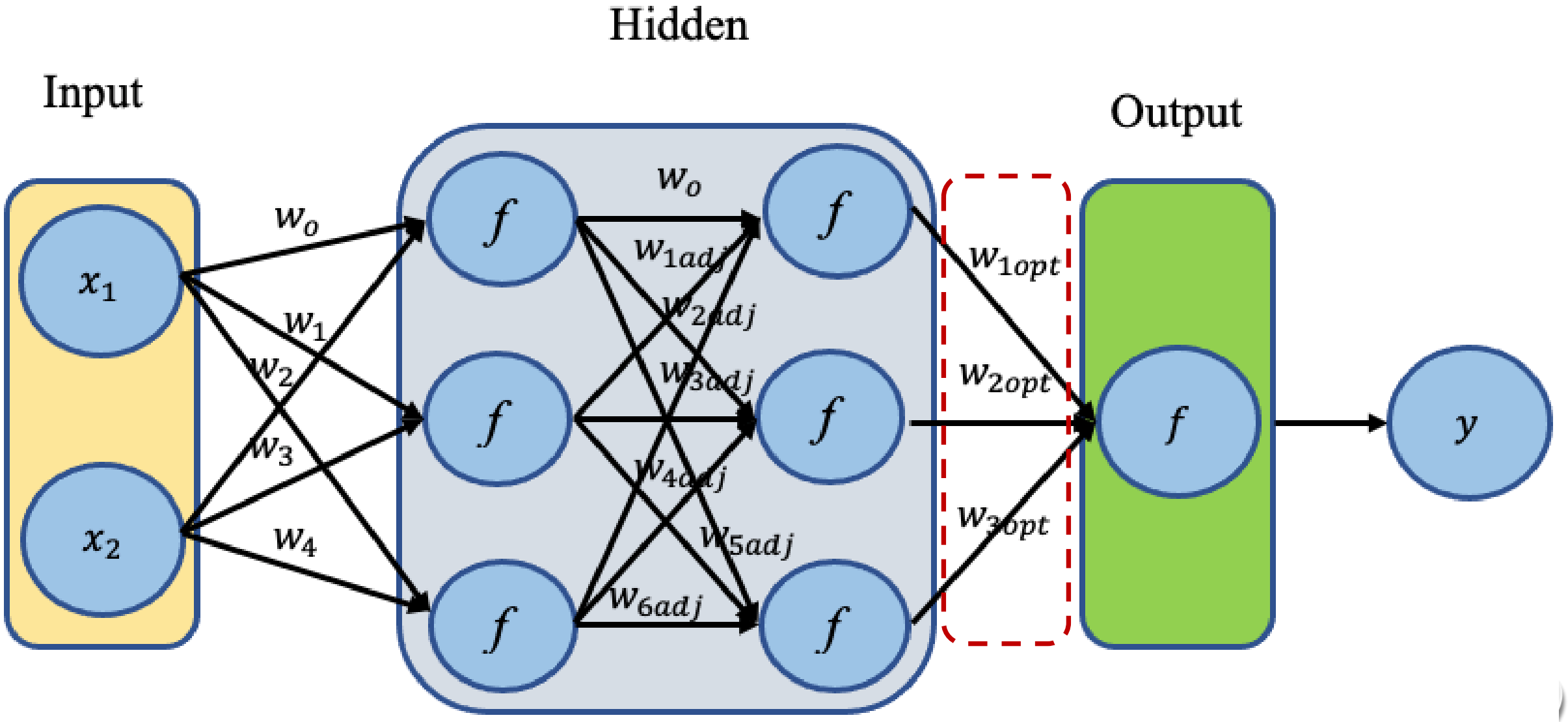
5. HYBRID MODEL

Several methods currently exist to simulate nickel prices; however, no single method consistently delivers high forecasting performance. **Consequently, the combination of various forecasting methods has emerged as a strategy to enhance overall forecasting accuracy** (Mehdi & Bijadi, 2011) (Kristjanpoller & Minutolo, 2015) (Kristjanpoller & Hernández, 2017) (Alameer, et al., 2019).

The combination of various Bayesian scenarios using dynamic model averaging was introduced by (Drachal, 2019) to forecast the spot prices of lead, zinc, and nickel. (Shao, et al., 2019) introduced a **combination of an improved particle swarm optimization (PSO) algorithm with long short-term memory (LSTM) networks** to forecast nickel prices. To forecast medium- to long-term nickel prices, (Ozdemir, et al., 2022) proposed **combining Long Short-Term Memory (LSTM) networks with Gated Recurrent Units (GRU).**



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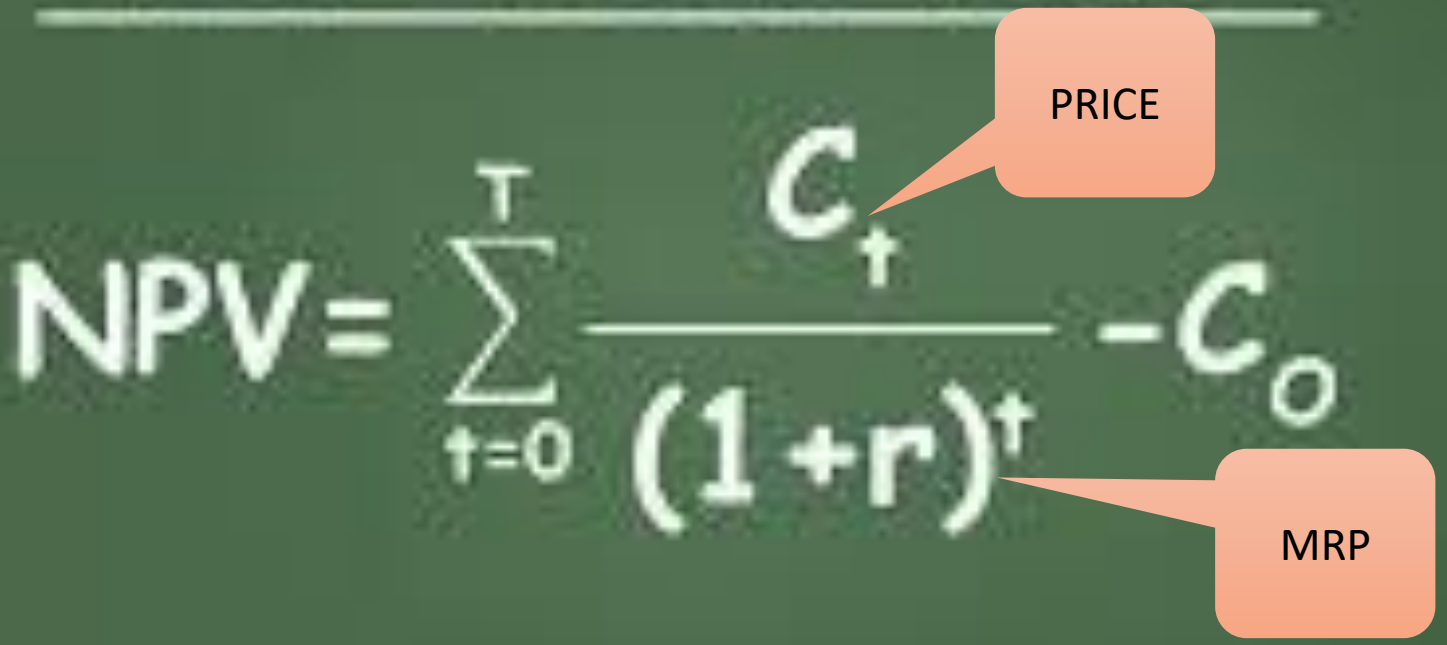
Net Present Value



C_t = net cash inflow during the period t
C_0 = total initial investment costs
r = discount rate
t = number of time periods

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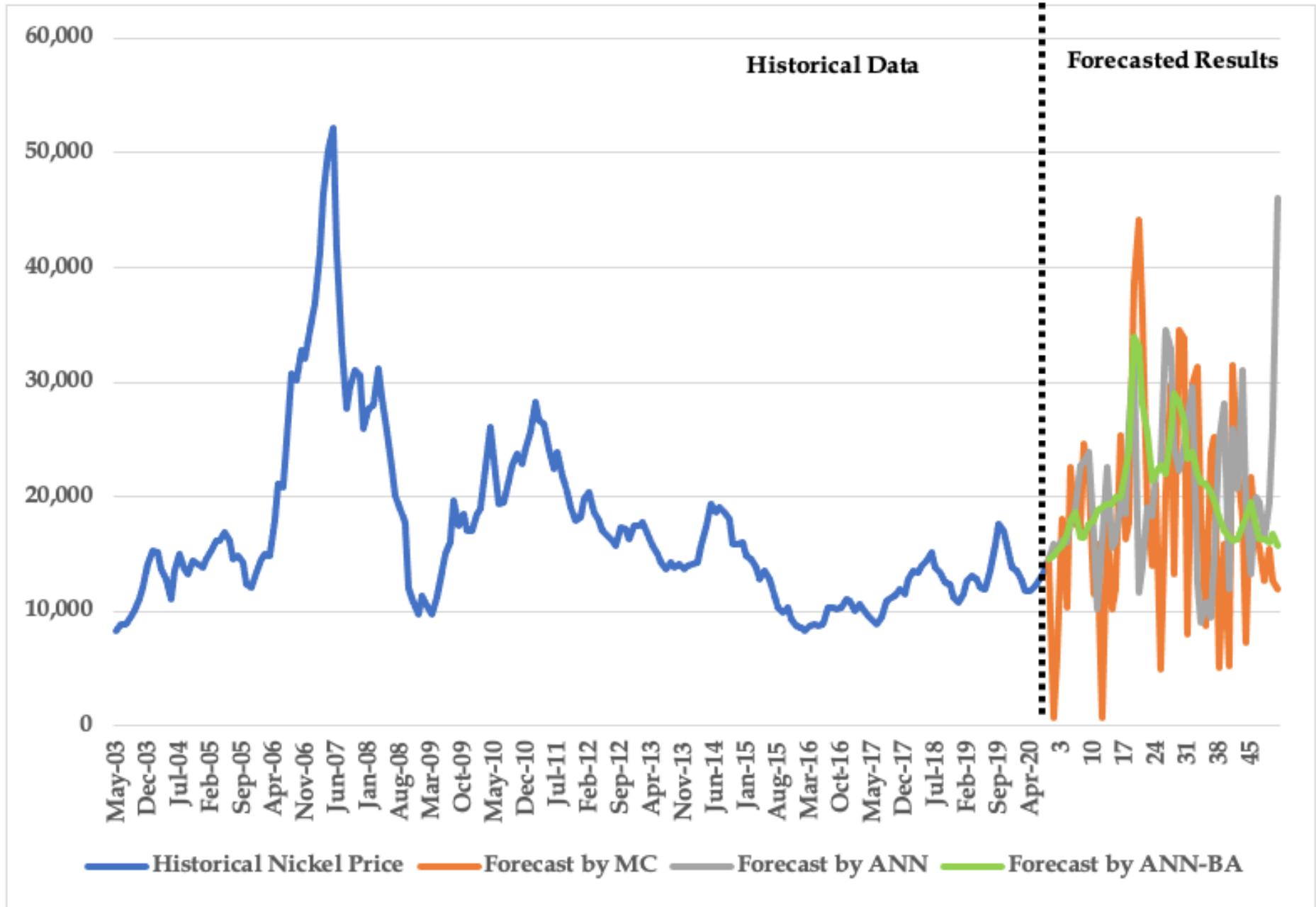

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Figure 13. Historical and forecasted nickel prices

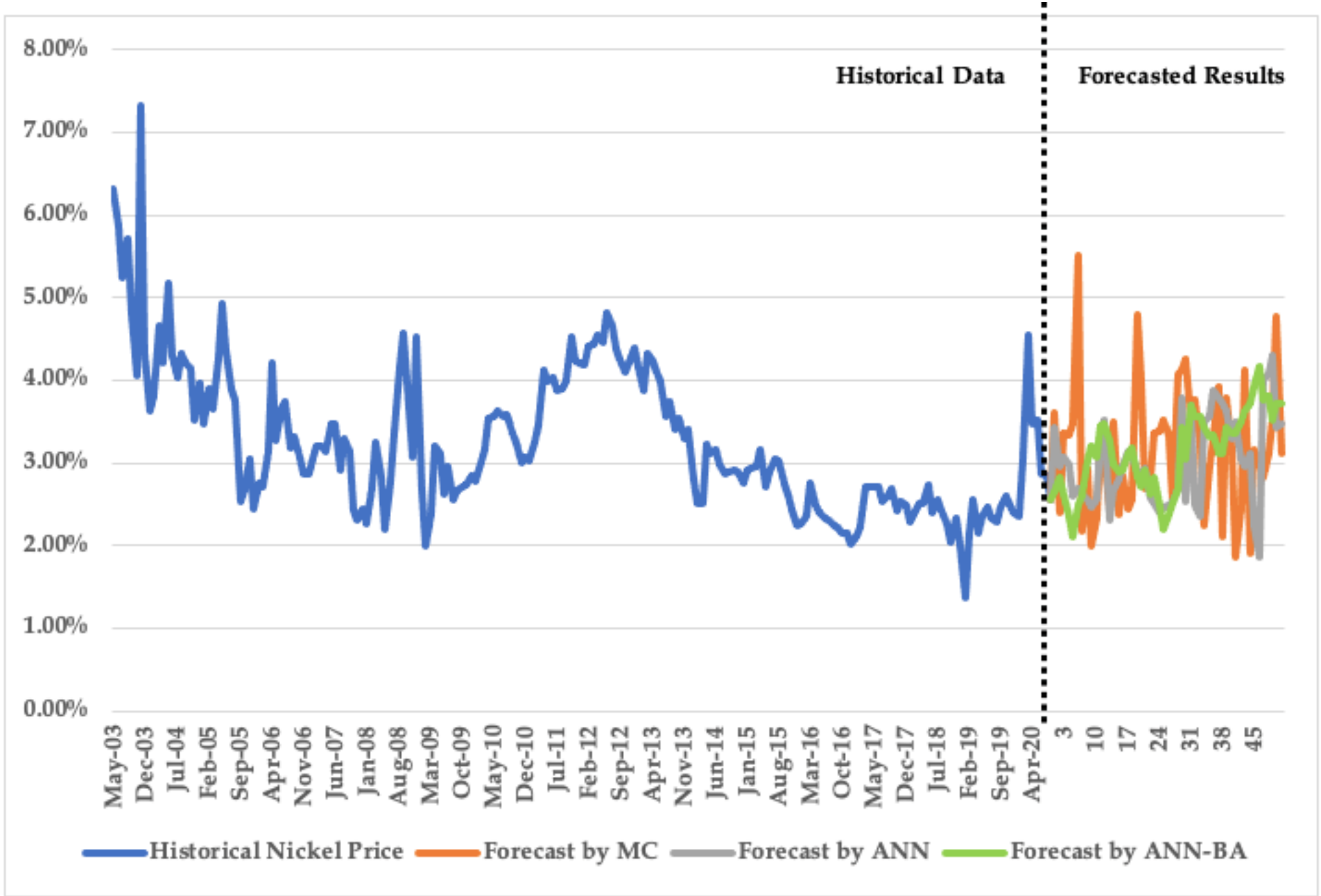

Figure 14. Historical and forecasted the MRP

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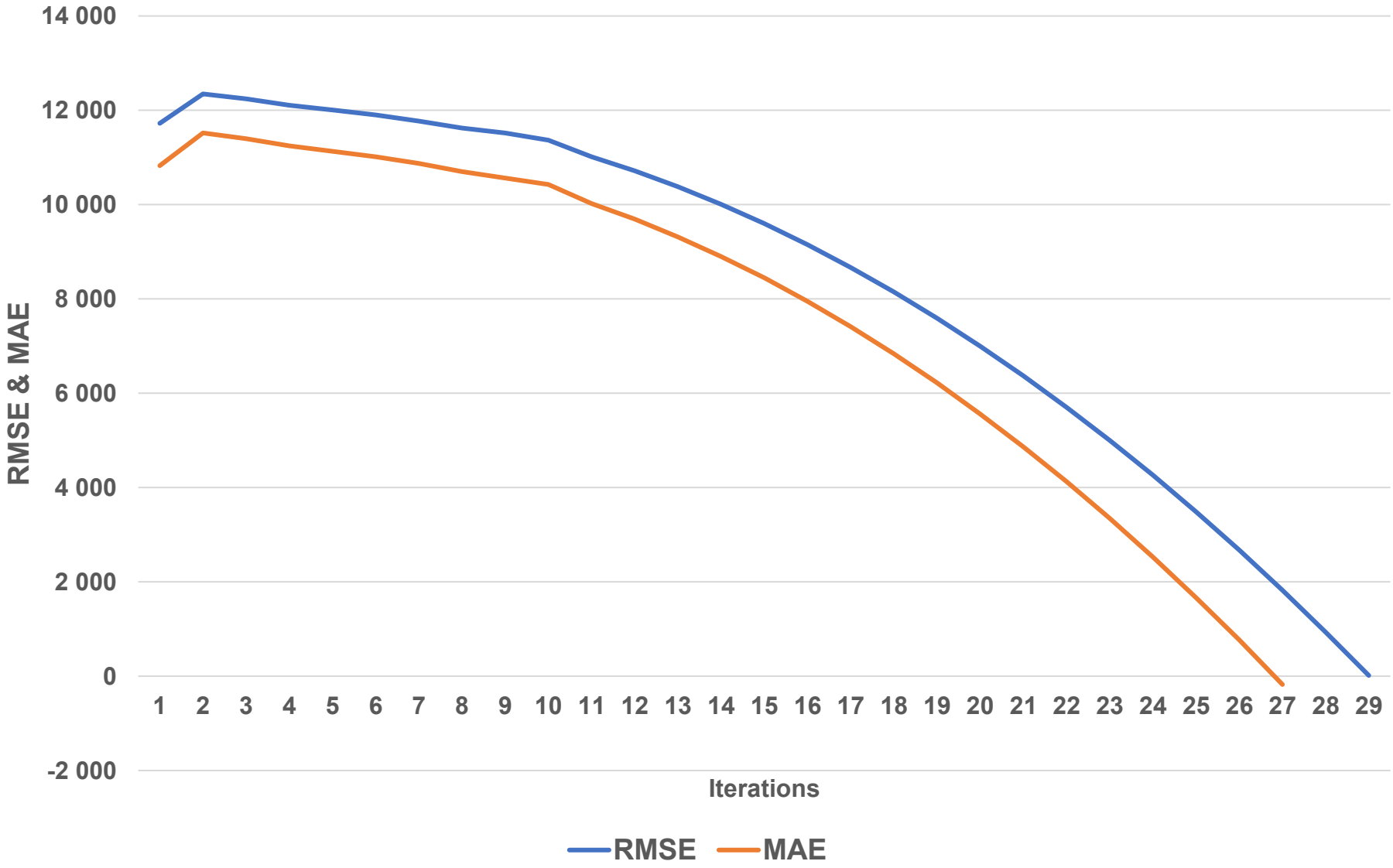

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	Monte Carlo (MC) Simulation	Artificial Neural Network (ANN)	Artificial Neural Network - Bat Algorithm (ANN-BA)
RMSE	20,311	8,109	15
MAE	18,307	5,789	13

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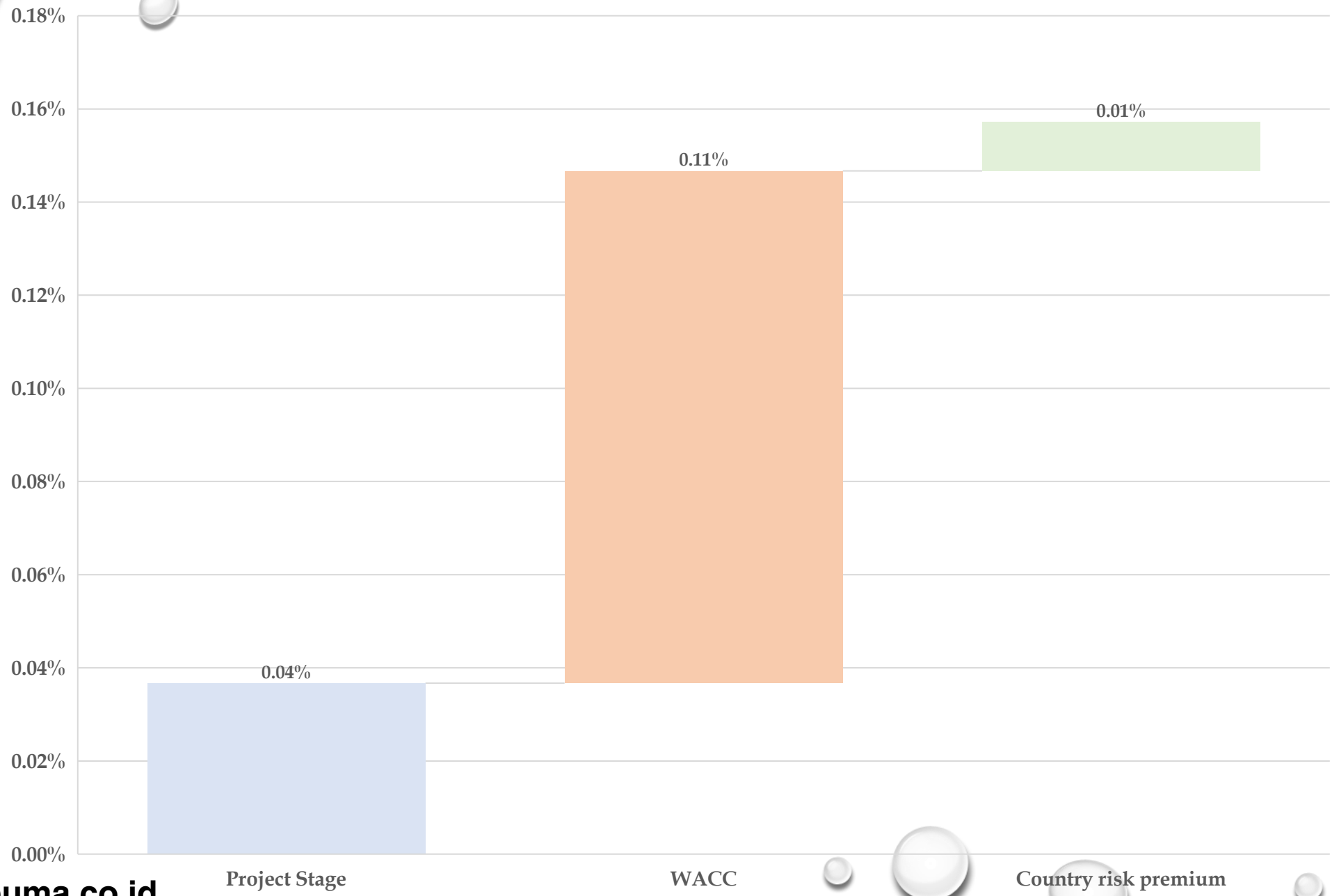

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Adjust for country risk

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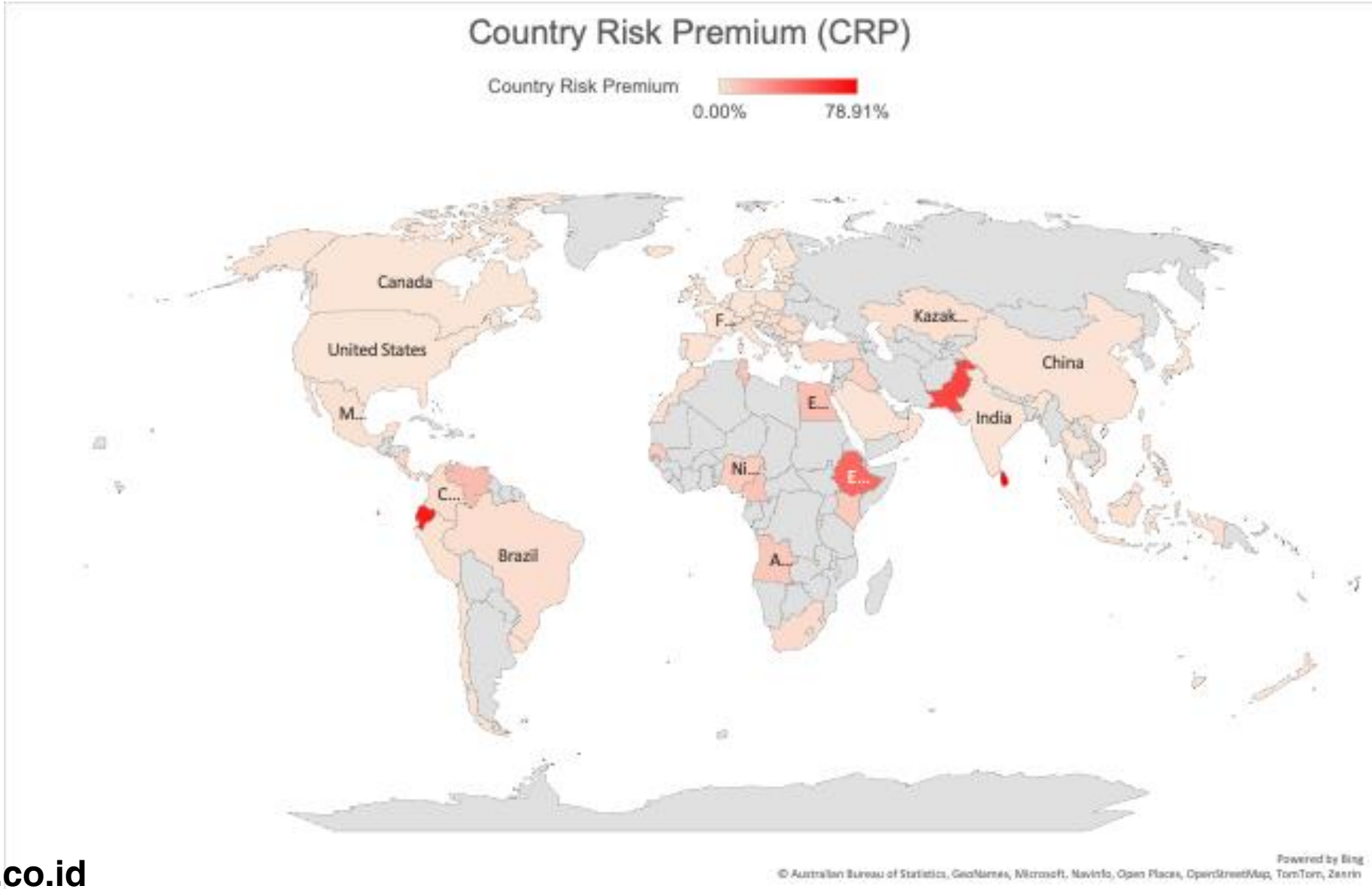

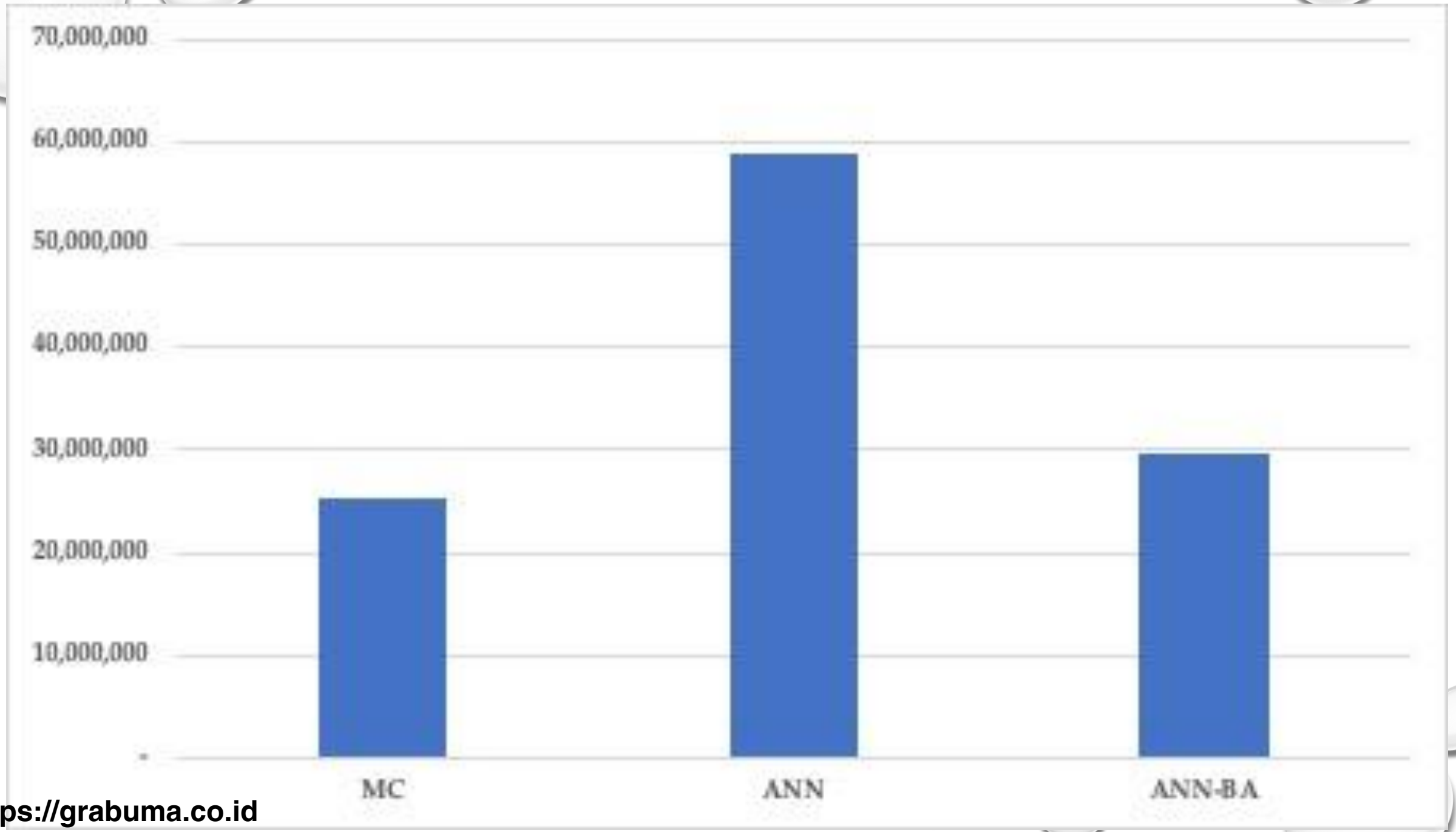

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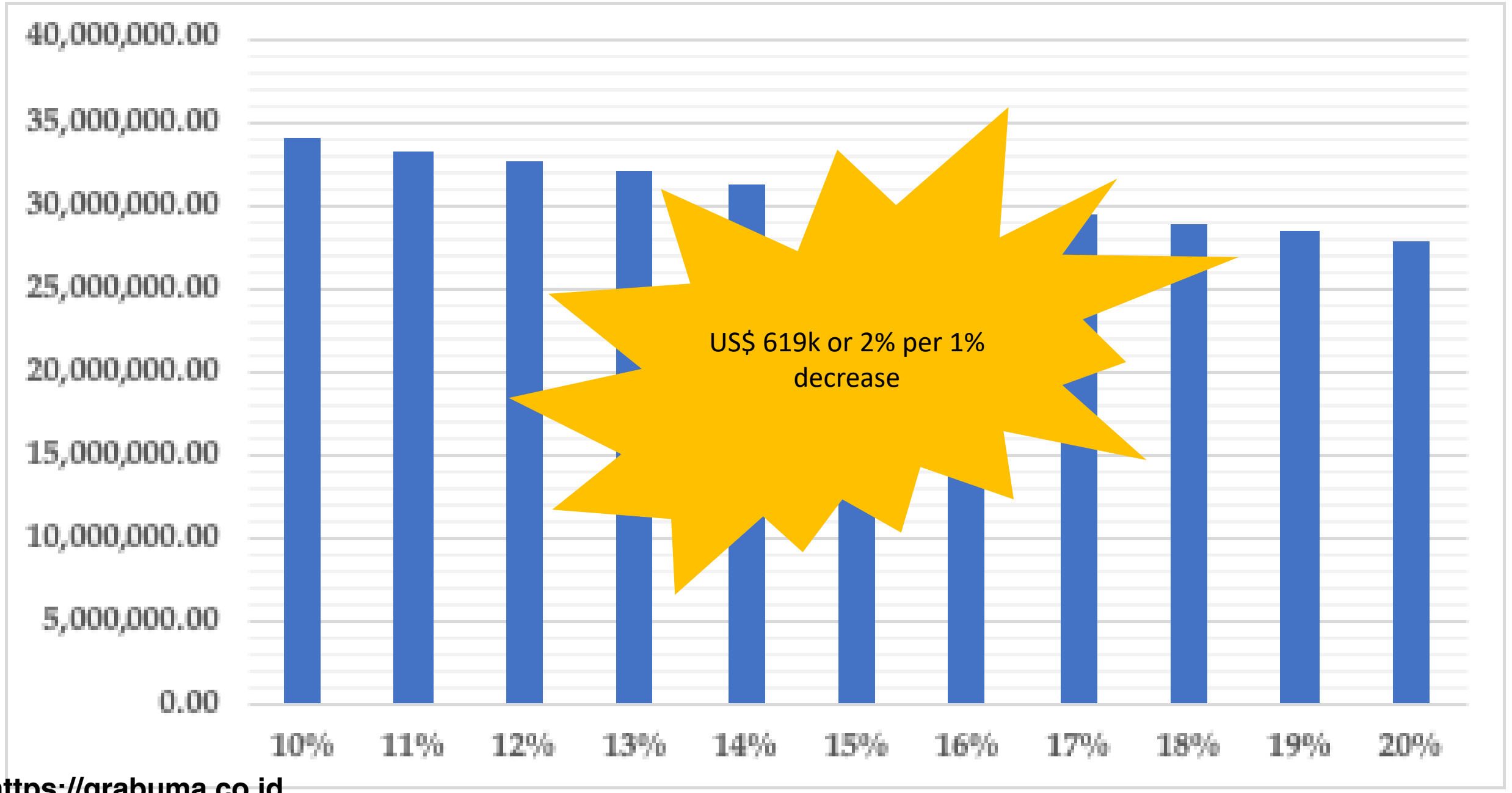

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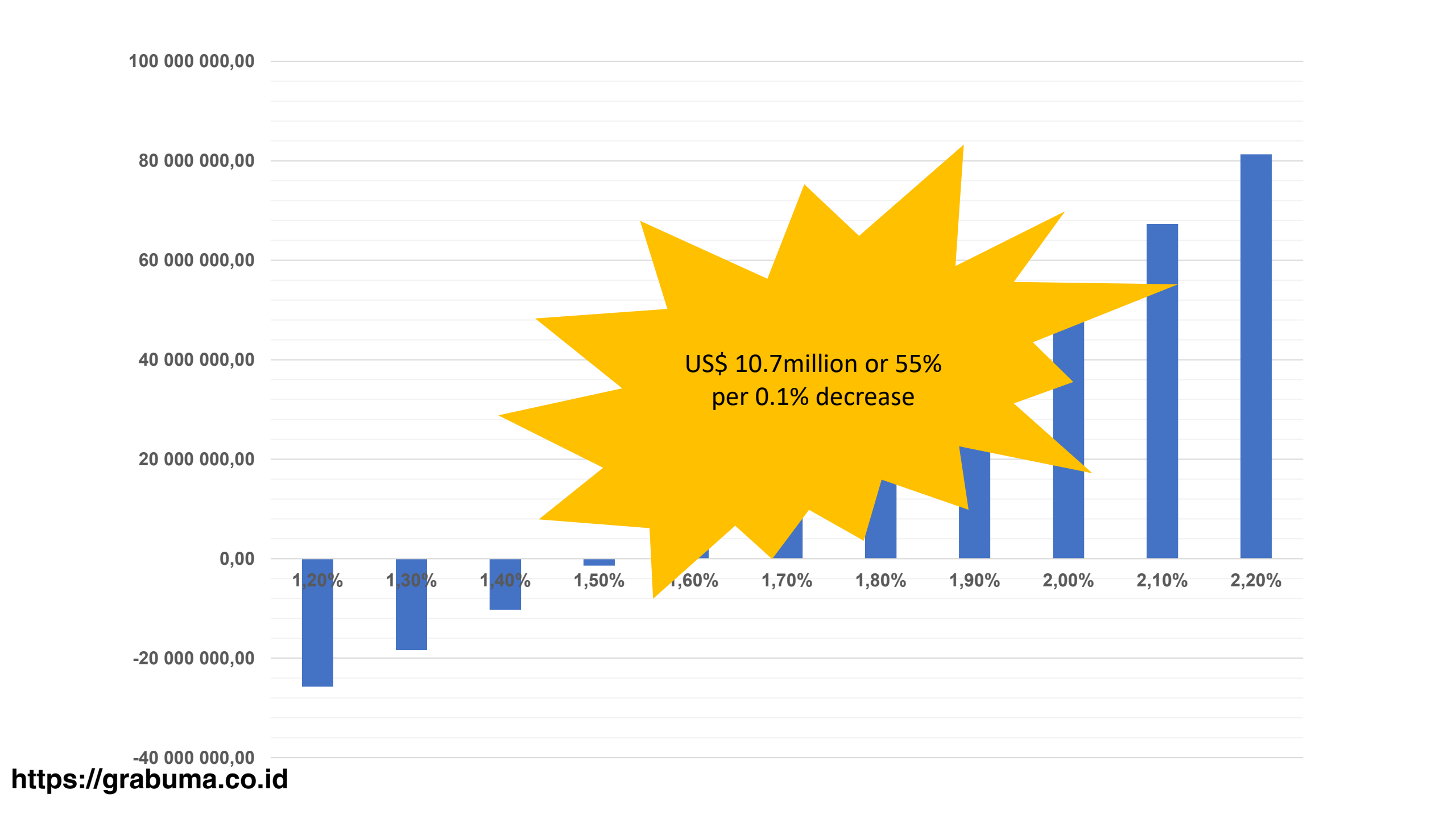

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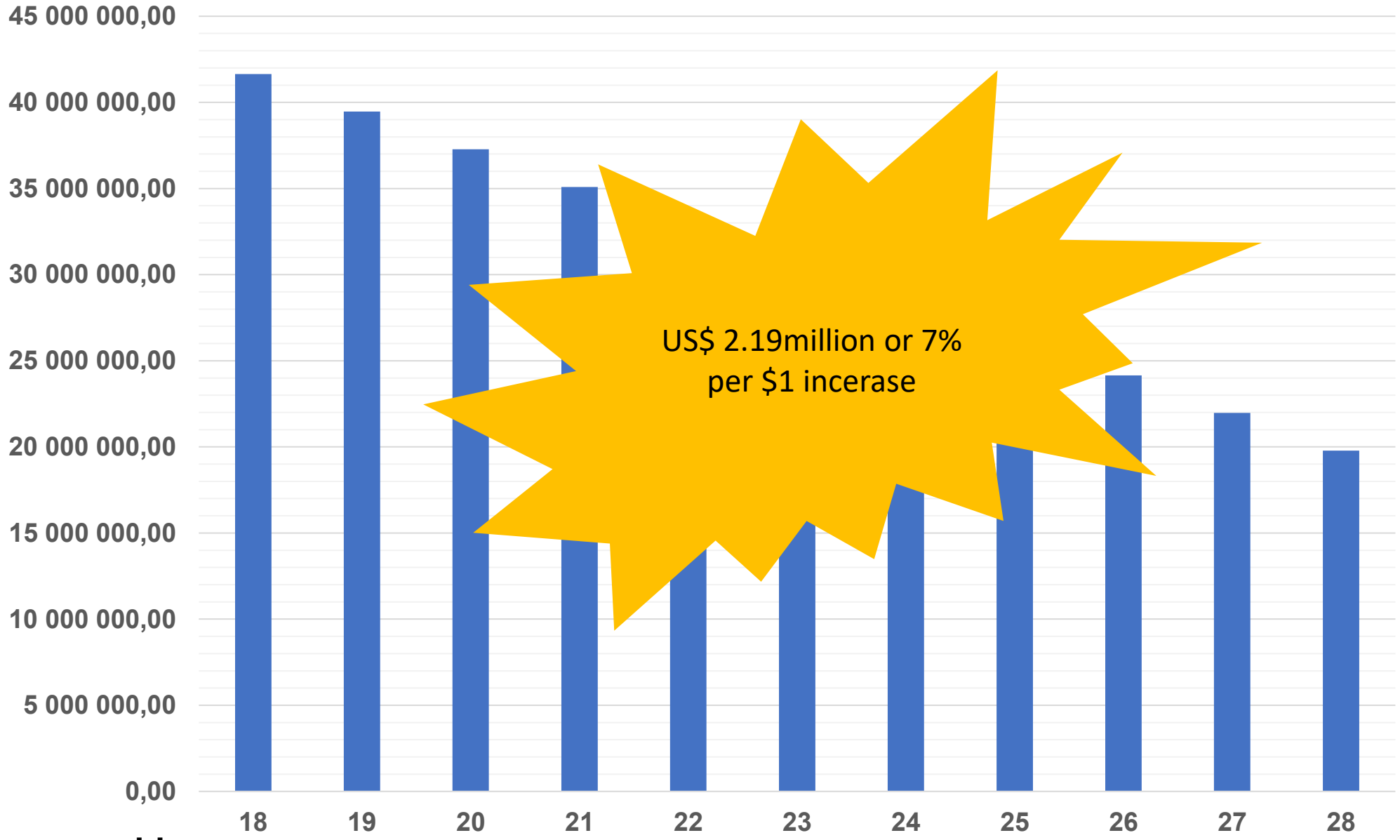

https://grabuma.co.id

рахмат
ngiyabonga
danke
謝謝
spas
teşekkür ederim
Баярлалаа
mersi
kia ora
barka
welalin
tack
mahalo
tapadh leat
спасибо
faafetai lava
vinaka
blagodaram
dank je
misaotra
paldies
grazzi
спасибі
matondo
thank you
gracias
хвала
kiitos
dankie
nanni
nandri
dhanyavad
mauruuru
köszönöm
ačiū
asante
manana
obrigada
tenki
bedankt
bayarlalaa
gràçie
hvala
dankon
akun
enkosi
djiere dieuf
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murakoze
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chokrane
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go raibh maith agat
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obrigado
sukriya
kop khun krap
sagolun
arigatô
takk
dakujem
trugarez
mèsi
didi madloba
ありがとう
tanemirt
grazie
najis tuke
terima kasih
rahmet
ευχαριστώ
diolch
dhanyavadagalu
shukriya
mercé
мерси
kam sah hamnida
rahmat
তোমাকে ধন্যবাদ
감사합니다
xièxie
merci